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Rio Blanco Oil Shale Project

REVISED DETAILED DEVELOPMENT PLAN TRACT C-a

VOLUME 2

MINING, PROCESSING and SUPPORT FACILITIES

Gulf Oil Corporation - Standard Oil Company (Indiana)

May, 1977

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RIO BLANCO OIL SHALE PROJECT

REVISED
DETAILED DEVELOPMENT PLAN
TRACT C-a

VOLUME 2

SECTION 2 MINING

SECTION 3 PROCESSING

SECTION 4 PROCESSED SHALE & DEVELOPMENT ORE DISPOSAL

SECTION 5 SUPPORT FACILITIES

Submitted To Area Oil Shale Supervisor,
Geological Survey, U.S. Department of the Interior,
Pursuant To Lease No. C-20046

Gulf Oil Corporation – Standard Oil Company (Indiana)

May, 1977

REVISED DDP ABSTRACT

In 1969, the U. S. Department of the Interior initiated planning for a prototype oil shale leasing program that eventually resulted in Gulf Oil Corporation and Standard Oil Company (Indiana) acquiring an oil shale lease for Tract C-a in the Piceance Creek basin of northwest Colorado. Gulf and Standard submitted the high bonus bid for Tract C-a ($210,305,600) at a lease sale in Denver on January 8, 1974. Rio Blanco Oil Shale Project (RBOSP), an organization directed and staffed by representatives of Gulf and Standard, was formed later that year for the purpose of developing the tract.

RBOSP has conducted extensive geotechnical and environmental data collection programs to establish baseline conditions on and around Tract C-a and to provide input for the selection of mining and processing plans. This revised Detailed Development Plan (DDP) describes RBOSP's proposed development and operation of a commercial-scale oil shale complex and support facilities on and around Tract C-a. The development plan, environmental protection plans and environmental monitoring programs are based on the best technology presently available. Specific details of the engineering and environmental projections will change because of continually improving technology in these areas. RBOSP will be flexible and responsive to changes in information and technology and will incorporate new information into the project plans wherever warranted.

Before RBOSP can proceed with development of Tract C-a, several approvals and permits must be obtained from County, State and Federal governments. Among these are approval of the DDP, and acquisition of necessary rights-of-way and all permits for construction and operations, which presupposes the emissions and effluents from the operation will be acceptable under State and Federal regulations.

PROJECT DESCRIPTION

This revised DDP presents a 40-year plan for developing the oil shale resource on Tract C-a. This includes a 10-year Modular Development

Phase and a 30-year Commercial Phase. At the end of that time, approximately one-half of the tract will have been developed. RBOSP will develop the resources consistent with environmental, technical and economic constraints which prevail now or may exist in the future.

Development will consist of Modified In Situ (MIS) recovery of shale oil, on-tract surface retorting of the material brought to the surface, on-tract disposal of processed shale and waste materials and on-tract support facilities. The MIS method to be used by the Rio Blanco Oil Shale Project employs well known sublevel caving mining methods in combination with technology similar to in situ recovery of heavy oil from sand reservoirs in conventional oil fields. Mining involves the sinking of vertical shafts followed by development of rubblized zones which become underground retorts. The deposit is divided into cells of rubblized oil shale separated by pillars of undisturbed oil shale. Because most retorting occurs underground, the need for large off-tract processing and disposal areas is eliminated. The MIS method is considered by RBOSP as the best technique for achieving a combination of good resource recovery, minimum environmental impact and economic acceptability.

The two phases of the MIS operations include a Modular Development Phase and a Commercial Phase. The Modular Development Phase will consist of underground retorting only and will be conducted near the center of the commercial mine area during the first 10 years of operation (1977-86, including construction). During this time period, a number of retorts will be built and burned in sequence to gain operating experience, improve process efficiency, and confirm capital and operating costs for a commercial operation. The beginning of construction for the Modular Development Phase and all subsequent dates is keyed to timely approval of the DDP and the end of the suspension of operations granted by the Department of the Interior in 1976.

Engineering and construction for the Commercial Phase will begin in 1982 after results of the first prototype commercial-size retort, to be built

in 1981, have been analyzed. Completion of commercial-size retorts and support facilities is anticipated to take up to five years. During this period, single commercial-size prototype retorts will continue to be burned as part of the Modular Development Phase. Table 1 is a summary of information pertinent to RBOSP's proposed development of Tract C-a. Figure 1 depicts the location of proposed facilities.

The Modular Development Phase consists of developing several retorts off the same shaft. Retorts 1 and 2, starting in 1979, will allow evaluation of the retorting model prediction, provide practical field operating experience and supply samples for laboratory and field experiments. Retorts 3 and 4 will test mining concepts and the scaling-up of the size of the retorts. These two retorts will be developed and burned in 1980 and 1981.

Commercial scale operating conditions will be demonstrated in Retort 5 and beyond, with operations beginning in 1981. These retorts are large enough to be developed by the sublevel caving method. Objectives for the remaining prototype commercial retorts are to evaluate commercial-size retorts and continue to optimize both mining and retorting operations while the commercial facilities are under construction.

The shale oil produced in all Modular Development Phase retorts will be pumped to the surface and trucked to a market point. During this phase, a permit will be obtained from the Colorado Department of Health to thermally oxidize the gases before they are vented to the atmosphere. Mined material in the Modular Development Phase will be trucked from the mine and used for fill as required; the balance will be piled and re-vegetated.

Engineering and conceptual design work on the proposed facilities is based on producing 76,000 barrels per stream day (BPSD). This higher production rate resulted from conservative original estimates of component capacity. However, RBOSP intends to demonstrate commercial feasibility and other objectives of the prototype oil shale program at

an initial rate of about 50,000 BPSD. Should future conditions warrant, production could be expanded to 76,000 BPSD.

All environmental assessment was based on 76,000 BPSD production rate. The assessments and models show that RBOSP can satisfy environmental stipulations and regulations at this higher production rate. They can easily be met at the rate of 50,000 BPSD since environmental effects will be reduced in proportion to plant capacity.

Table 1

RIO BLANCO PROJECT SUMMARY

	MODULAR DEVELOPMENT PHASE	COMMERCIAL PHASE
Timing		
Construction	Sept. 1977-Oct. 1979	June 1982-Jan. 1987
Operation	Begin Oct. 1979	Begin Feb. 1987
Mine Development		
Ore Production (Average Brought to Surface)	Retorts 1-5, 500 TPSD Retorts 6 & up, 3000 TPSD	40,000 TPSD
Ore Rubblized (In Situ)	Up to 12,000 TPSD	134,000 TPSD
Ore Haulage (Surface)	Truck	Belt Conveyors
Processing		
Retorting-Surface	-	TOSCO II
Retorting-Underground	Modified In Situ	Modified In Situ
Processed Shale Haulage	-	Belt Conveyors
Products		
Shale Oil	Up to 4000 BPSD	76,000 BPSD
Sulfur	-	265 LTPSD
Product Movement	Truck (Shale Oil)	Pipeline (Shale Oil) Truck (Sulfur)
Net Groundwater Used	Up to 1000 AFY	2200 AFY
Power (Purchased)	Up to 40 MW	100 MW
Peak Employment	2500 for 76,000 BPSD 1900 for 50,000 BPSD	2075 for 76,000 BPSD 1550 for 50,000 BPSD

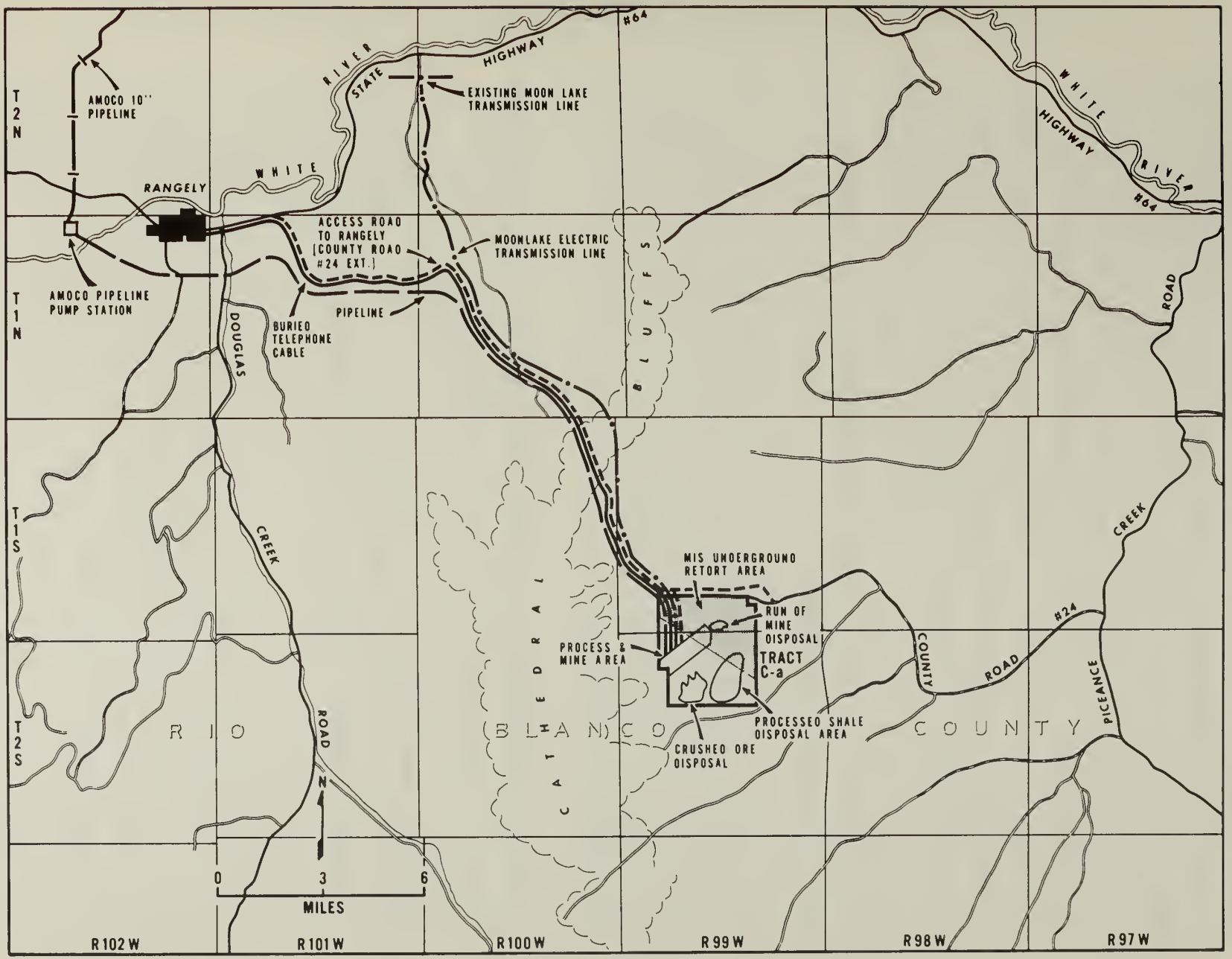

Figure 1

LOCATION OF RBOSP FACILITIES

Information learned from early commercial-size retorts will be used for engineering and construction of commercial production and service shafts, surface retorts, and support facilities beginning in 1982. The rubblized retorts for the Commercial Phase are designed to have void ratios of approximately 20% produced by mining and rubblization. Underground retorting by the Modified In Situ method could produce up to 57,000 BPSD. The ore produced in developing the voids will be crushed underground and stockpiled on the surface. The material will then be surface retorted to produce up to an additional 19,000 BPSD, bringing the total shale oil production to 76,000 BPSD. Sulfur will be recovered during the commercial operation. The low BTU offgases produced in the Commercial Phase will be utilized for power generation to supply most of RBOSP's electrical requirements.

The MIS retorts for 30 years of commercial production includes the richest, thickest oil shale within Tract C-a which is located in the northeast quadrant. The area proposed for retorting represents 10 years of modular development plus 30 years of commercial production and consists of about one-half of the tract.

Location of the disposal site for processed shale and the plant site are both on Tract C-a. Rinky Dink Gulch was selected for processed shale disposal because it is on tract and in an area of minimum surface drainage. Operationally, it is sufficient in size to hold the waste products and is close to the processing operations. Investigations are underway to determine if part or all of the processed shale could be injected into the spent retorts by slurrying for (1) ground stabilization, (2) sealing the retorts against leaching by groundwater, and (3) disposal of the processed shale. Selection of the processing facility site was based on its close proximity to the mine and disposal area which will reduce acreage disturbance. Also, the elevated topography will enhance dispersion of stack emissions and the relatively level terrain will minimize disturbance.

During the Modular Development Phase, the ore removed to create the 20% underground void volume will be transported to the disposal area by truck. During the Commercial Phase, it will be transported from the MIS mine area to the processing facility by belt conveyor. After surface retorting, processed shale will be transported to the disposal area from the plant site by belt conveyor. As final slopes are established on the disposal pile, the processed shale will be covered by coarse, crushed materials and covered with soil from the disposal areas. The disposal pile will be contoured, revegetated and progressively reclaimed as operations proceed.

During the Modular Development Phase, shale oil will be trucked to an existing refinery or markets. In the Commercial Phase, shale oil will be transported by pipeline to Rangely, Colorado. It will then be pumped through an existing Amoco pipeline to other connecting carriers for ultimate delivery to refineries or markets in the West or Midwest. If necessary, flow improvers will be added to the raw shale oil to make it a pipelineable product. The by-product sulfur recovered from retorting will be trucked from Tract C-a to rail facilities near Rifle, Colorado.

Mine dewatering during the Modular Development and Commercial Phases will produce more water than is required for project needs. This excess water will be reinjected off-tract into the basin's aquifers. Up to 1000 acre-feet/year (AFY) of groundwater will be used during the Modular Development Phase, obtained from mine seepage and/or the dewatering wells. During the Commercial Phase, approximately 2200 AFY of groundwater will be used.

RBOSP will require the purchase of up to 40 megawatts (MW) of electricity during the Modular Development Phase operations. The demand will increase to about 100 MW during the Commercial Phase. Moon Lake Electric Association will supply electricity to Tract C-a via a 138 KV transmission line from an existing line near the White River 20 miles north of the tract. RBOSP will utilize the low BTU gas produced from MIS retorting to produce most of its electric power needs during the Commercial Phase.

Mountain Bell Telephone Company will provide communications from Rangely for commercial construction and operations. Vehicular access to Tract C-a will be via Rio Blanco County Road 24 (Ryan Gulch Road) from the east and via an extension of this road from the tract to Rangely on the west. The power transmission line, shale oil pipeline, and access road will be located, wherever possible, in a common corridor between Rangely and Tract C-a in accordance with the present Bureau of Land Management corridor concepts.

BASELINE ENVIRONMENTAL AND GEOTECHNICAL CONDITIONS

Collection of baseline environmental data on and around Tract C-a began in October, 1974. Since individual tasks started at various times, two full years of collection in some categories were not completed until early February, 1977. The program was designed to gather extensive environmental data for the purposes of (1) complying with lease stipulations to describe baseline environmental conditions prior to development and, (2) developing a scientifically sound environmental data base to help in the design of an environmentally acceptable DDP. During planning and development of the baseline programs, environmental lease stipulations were subjected to critical review. Potential data gaps inherent in the stipulations were identified and suggestions for amendments to the lease were made.

After thorough evaluation and study, a final scope of work was submitted to and approved by the Area Oil Shale Supervisor (AOSS) following review and recommendation by the Oil Shale Environmental Advisory Panel.

Programs were developed to study several areas of environmental concern including meteorology and air quality, and terrestrial and aquatic ecology. The programs were also designed to describe interrelationships among components of the ecosystem and identify areas of cultural resources. The environmental baseline conditions and analyses upon which the DDP environmental information is based were submitted as a separate report to the AOSS in May, 1977 entitled "Final Environmental Baseline Report for Tract C-a and Vicinity."

Geotechnical data gathering, including geologic and hydrologic resource evaluation through core hole drilling and geophysical logging, began in July of 1974. The geologic program conducted by RBOSP provides detailed structural, stratigraphic and resource data.

The hydrologic program conducted by RBOSP provides the data for determining the hydrologic environmental baseline, aquifer characteristics, and quality and quantity of water expected to be produced from various mining plans.

ENVIRONMENTAL PROTECTION

RBOSP's plan is to construct and operate an environmentally acceptable oil shale operation. Specific environmental protection procedures have been developed to ensure compliance with lease provisions and with all applicable Federal, State and local environmental protection and pollution control regulations. The procedures and mitigation plans are designed specifically for RBOSP's intended development of Tract C-a and will be modified as necessary with changing conditions. The protection procedures described in the development plan cover the following topics:

- Health and Safety
- Air Quality Control
- Water Quality Control
- Solid Waste Control
- Noise Control
- Aesthetics
- Abandonment
- Fish and Wildlife Management
- Land Rehabilitation
- Oil and Hazardous Materials Control
- Fire Prevention and Control
- Protection of Objects of Historic and Scientific Interest
- Subsidence Control

RBOSP's assessment of potential environmental impacts which could result from Tract C-a activities include studies of air and water quality, terrestrial and aquatic biology, and cultural resources. Assessments were based on emissions, dispersion modeling and tracer studies, water flow modeling, and in-depth analyses of environmental baseline.

Environmental monitoring programs have been designed to provide data which will identify impacts to the environment resulting from development activities. Changes from conditions existing prior to development as established by the baseline data collection program will be recorded. These programs will allow evaluation of the success of the mitigation plans. Should the monitoring programs show that the control plans are not working as predicted, the control plans will be modified to enhance their effectiveness.

A monitoring program has been initiated since the baseline programs were completed on Tract C-a. Monitoring will continue, as the lease requires, until the Area Oil Shale Supervisor determines to his satisfaction that environmental conditions consistent with Federal and State statutes and regulations have been established.

SOCIAL AND ECONOMIC PLANNING

Gulf and Standard began working with the people of northwestern Colorado shortly after acquiring the Tract C-a lease in 1974. Recognizing the importance of dealing with the potential social and economic impacts of oil shale development, the companies participated in planning with local, County, State and Federal governmental agencies.

Although a social and economic impact statement was not required by the Tract C-a lease, RBOSP officials and the Area Oil Shale Supervisor felt such a plan was desirable. Therefore, the Social and Economic Impact Statement for Tract C-a was submitted as a separate document along with the Detailed Development Plan. An addendum which updates the statement was submitted with the revised DDP.

The overall objective of the plan is to reduce negative impacts which have occurred in other areas because of industrial activity. In addition to the Social and Economic Impact Statement, Gulf and Standard sponsored the preparation of a master plan for the town of Rangely, Colorado, which has been adopted by the community and has been certified by Rio Blanco County.

DDP ORGANIZATION AND USE

RBOSP's DDP consists of 8 sections comprising 3 volumes, as depicted in the chart on page 12. Volume 1 is the "Executive Summary". If one is interested in an overview of the development plan, Volume 1 is recommended.

Volume 2 describes engineering plans for developing Tract C-a and includes sections on mining, processing, processed shale disposal and support facilities. Volume 3 describes RBOSP's environmental protection plans and also includes sections concerning environmental assessment and monitoring. The Confidential Volume, which is not publicly available, contains proprietary information concerning oil shale properties, ore reserves and cost estimates.

Except for this DDP abstract, a 3-number page numbering system is used throughout the development plan. Any given page number is unique in that it is not repeated elsewhere in the DDP. Page numbers are keyed to chapters within sections; page 2-6-15, for example, refers to Section 2, Chapter 6, page 15.

RIO BLANCO OIL SHALE PROJECT
MIS-DETAILED DEVELOPMENT PLAN ORGANIZATION

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SECTION 2
MINING

CHAPTER 1
INTRODUCTION

Section 2, Mining, provides a background of basic data, describes mine geometry and related facilities, and summarizes the activities required to (1) develop access to the Modified In Situ retorts; (2) rubblize these retorts; and (3) develop passageways for moving retort products (gas, oil and water) to the surface.

Eight Chapters, 2 through 9, are included in this section for the purpose of showing sequentially how the mining concept was developed and adapted to a Tract C-a Modified In Situ retorting operation. It is stressed that the resulting mine designs and plans require additional detailed engineering design before being implemented in the field.

Plans for the Tract C-a Modified In Situ retorting operation show mine development and shale oil production to include a Modular Development Phase (MDP) and a Commercial Phase. The MDP spans ten years, includes the start of mine development in 1977, and the start of shale oil production in 1979. The Commercial Phase overlaps the MDP with mine development starting during the last half of 1982 and shale oil production commencing in 1987, at the conclusion of the MDP. Production of Commercial Phase shale oil spans 30 years.

Chapters 2 through 5, Site Description, Geology, Hydrology, and Rock Mechanics, present a general overview of the background data that was used to develop mine design criteria. As an example, geological data on graben, other faults, and joint systems was used to develop design criteria for pillar sizing, retort orientation, and retort placement.

Chapter 6, Mine Design, describes and illustrates for both the Modular Development and Commercial Phases, mine geometry, development techniques, rubblizing techniques, material handling methods, and support operations.

Mine geometry refers to layout and size of mine openings. Development technique refers to the method of driving headings which includes drilling, blasting, loading, hauling and roof bolting. Rubblizing techniques refer to the mining method used to break the oil shale in retorts and remove a specified volume of broken rock. Material handling refers to the various methods used to transport broken rock from the mine face to a surface stockpile. Support operations refer to those activities that provide support to the mining operation, such as ventilation, mine water pumping, power, maintenance, and safety.

The safety segment of support operations is covered in this section, however, additional information is available in Section 6, Environmental Protection, Health and Safety.

Chapter 7, Schedules, provides schedules that summarize mine development and construction; retort preparation, rubblizing and burning; and mined rock production.

Chapter 8, Subsidence, describes predicted cumulative ground surface disturbances caused by the Modified In Situ retorting operations. The potential of subsidence and possible ways of minimizing it are covered in Section 6, Chapter 13, Subsidence Control.

Chapter 9, Mining Alternatives and Selection, reviews three mining options; open pit, underground room and pillar, and Modified In Situ, and presents the reasons for selecting the Modified In Situ method.

The mining plan, herein, is based on present knowledge, technology, and engineering studies that are continually changing. Therefore, it should be recognized that the mining plan will also change as new and more reliable knowledge is developed. From this, it is reasoned that the basic elements of the plan, together with conditions specified by the lease and applicable regulations are the principal elements subject for approval.

CHAPTER 2
SITE DESCRIPTION

2.1 TRACT C-a

A. Location - Tract C-a is located on the west side of the Piceance Creek basin, about 5 miles east of the Cathedral Bluffs skyline, in Rio Blanco County, Colorado. Access to the tract is about 60 miles by road from Rifle, Colorado, via State Highway 13, the Piceance Creek Road (County Road #5) and County Road #24. See Figure 2-2-1.

B. Size - Tract C-a is rectangular in shape, extends about 2.75 miles east-west, 3 miles north-south and occupies approximately 5,100 acres.

C. Topography - Surface topography of the tract consists of a fan-shaped series of moderate canyons and ridges that descend from the west and converge toward the northeast corner of the tract. Within the tract, elevations range from heights over 7400 feet along the western boundary to a low of about 6600 feet in Corral Gulch near the northeast corner. The elevation differentials between ridge tops and canyon floors range from 250 to 475 feet. See Figure 2-2-2.

2.2 MODULAR DEVELOPMENT PHASE (MDP)

A. Location - Surface facilities and surface projections of underground workings for the Modular Development Phase MIS mining and retorting operations are located on the north slope of Airplane Ridge, near the center of Tract C-a. See Figures 2-2-2 and 2-2-3.

B. Size - Approximately 60 surface acres are required for the Modular Development Phase mining surface facilities and to cover the related underground workings.

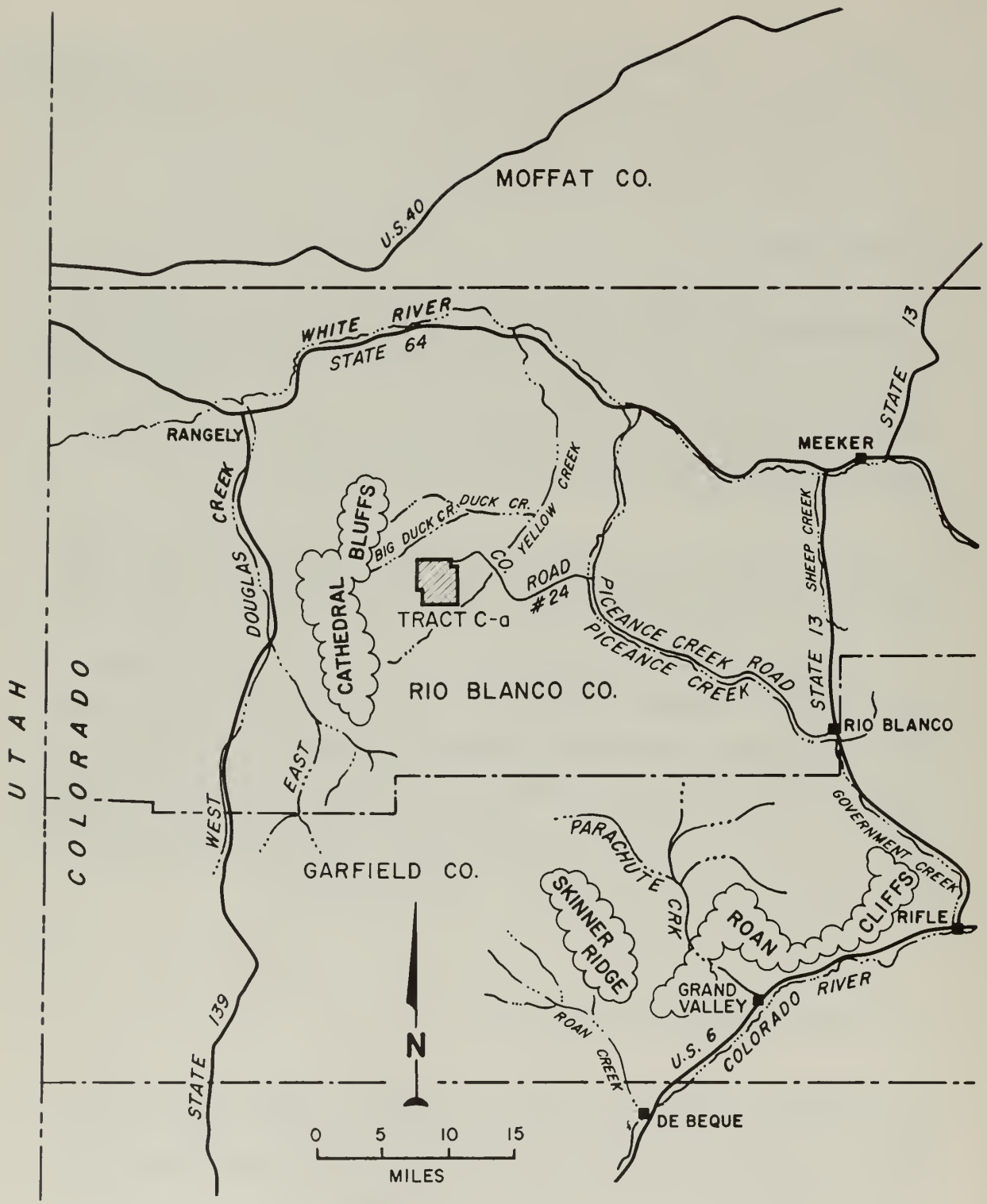


Figure 2-2-1
LOCATION MAP OF TRACT C-a

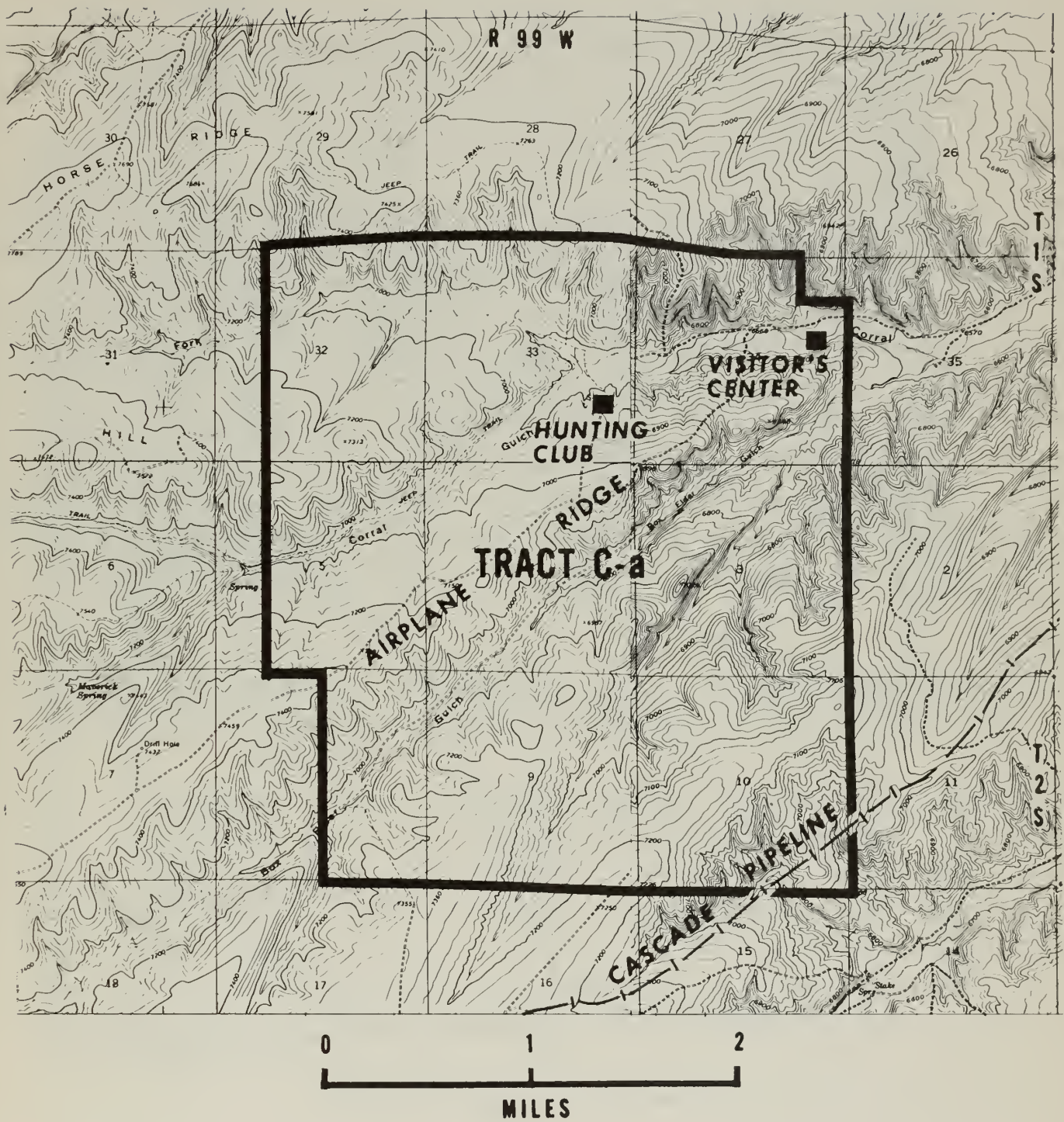


Figure 2-2-2
TOPOGRAPHY and CULTURAL FEATURES

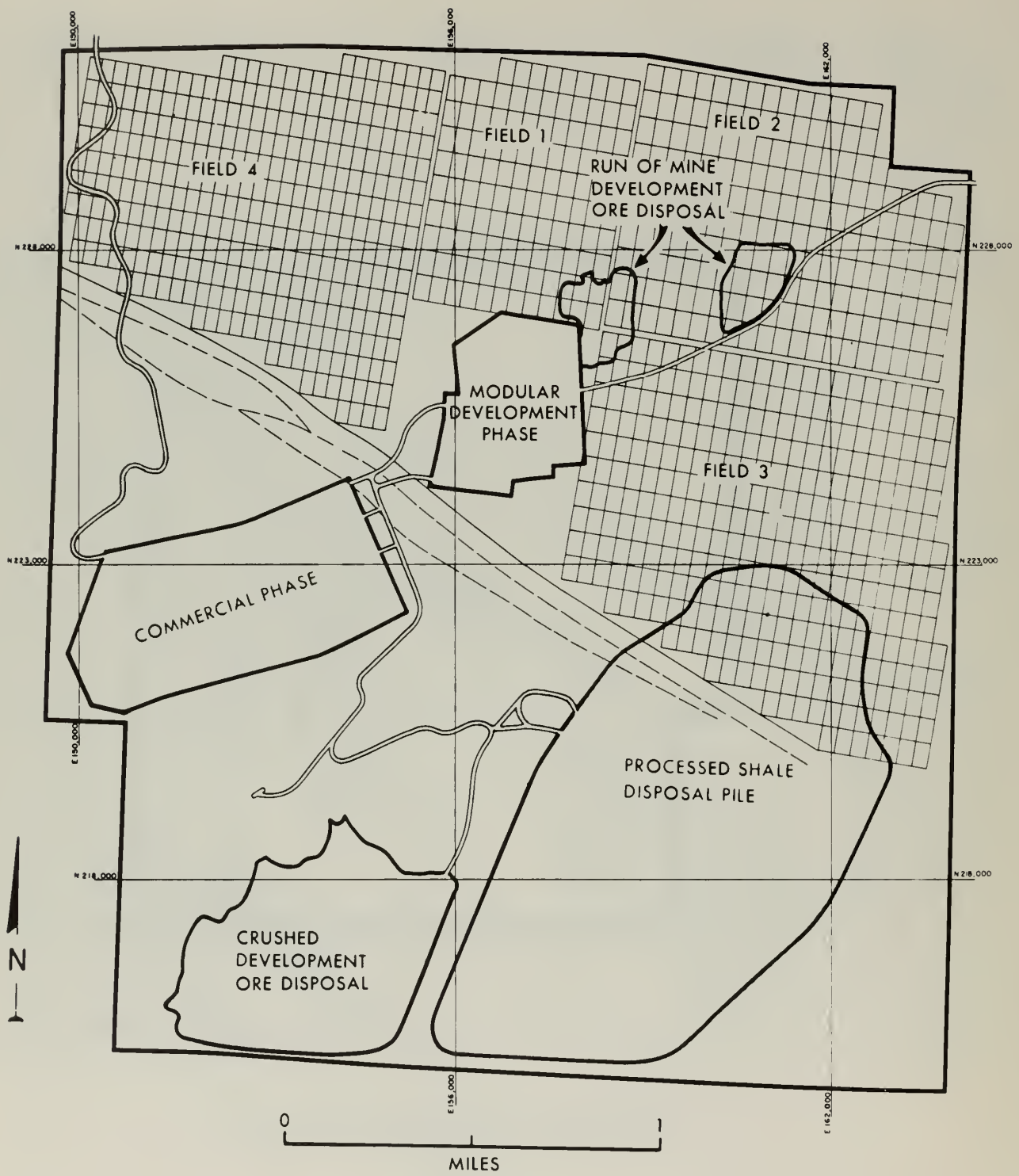


Figure 2-2-3
SITE PLAN

C. Topography - The mean elevation of the Modular Development Phase site is about 6950 feet with a high of about 7075 feet and a low of 6900 feet. The topography slopes down to the north from Airplane Ridge to Corral Gulch. See Figure 2-2-2.

2.3 COMMERCIAL PHASE

A. Location - Surface facilities and surface projections of underground workings for the Commercial Phase MIS mining and retorting operations are situated primarily in the northern half of Tract C-a, with their west, north and east limits bordering the Tract C-a boundary, and south limit traversing Tract C-a diagonally from Dry Fork on the west, southeast, to Wolf Ridge on the east. This area includes, from north to south, the south slope of Deadhorse Ridge, Dry Fork, the east end of Sagebrush Hill, Corral Gulch, Airplane Ridge, Box Elder Gulch, the north end of Rinky Dink Gulch and a small segment of Wolf Ridge. See Figure 2-2-3.

B. Size - Approximately 2200 surface acres are required for the Commercial Phase MIS surface facilities and to cover the related underground workings.

C. Topography - Surface topography consists of ridges and canyons that descend from the west, cross the tract, and exit to the northeast. Within the tract, elevations range from heights over 7300 feet in the northwest corner on Deadhorse Ridge to a low of about 6600 feet in the northeast corner where Corral Gulch exits. The elevation differentials between ridge tops and canyon floors range from 250 to 475 feet. See Figure 2-2-2.

CHAPTER 3
GEOLOGY

3.1 TRACT C-a

The following discussion briefly reviews the geology of Tract C-a and its relationship to the tract's development by Modified In Situ methods. Tract C-a and regional geology is presented in detail in RBOSP Progress Report No. 5 which is on file at the AOSO, Grand Junction, Colorado.

A. Stratigraphy - Figure 2-3-1 is a generalized stratigraphic column of Tertiary Eocene rocks in the Piceance Creek basin. No attempt is made to maintain vertical scale representative of individual unit thicknesses. It is designed to portray the relative positions of the basin's major Eocene stratigraphic units and the locations of key markers (both lithologic and electric log) within those units. Also shown are the stratigraphic positions of the main oil shale interval of the Parachute Creek Member, Green River Formation, and the oil shale interval defined within Tract C-a.

Figure 2-3-2 is a 3-core hole SW-NE cross section across Tract C-a oriented approximately normal to isopach or depositional strike of the main oil shale interval of the Parachute Creek Member. It is designed to show the tract's specific stratigraphic characteristics including the positions of four key electric log markers (A- and B-grooves, Blue and Orange markers) and two key lithologic markers (Mahogany marker and Mahogany bed). These six stratigraphic markers are not only areally persistent within Tract C-a but also throughout most of the Piceance Creek basin and are extremely useful in subsurface correlations.

Also shown on Figure 2-3-2 is the oil shale zonation established by RBOSP within Tract C-a. This zonation is based on one previously

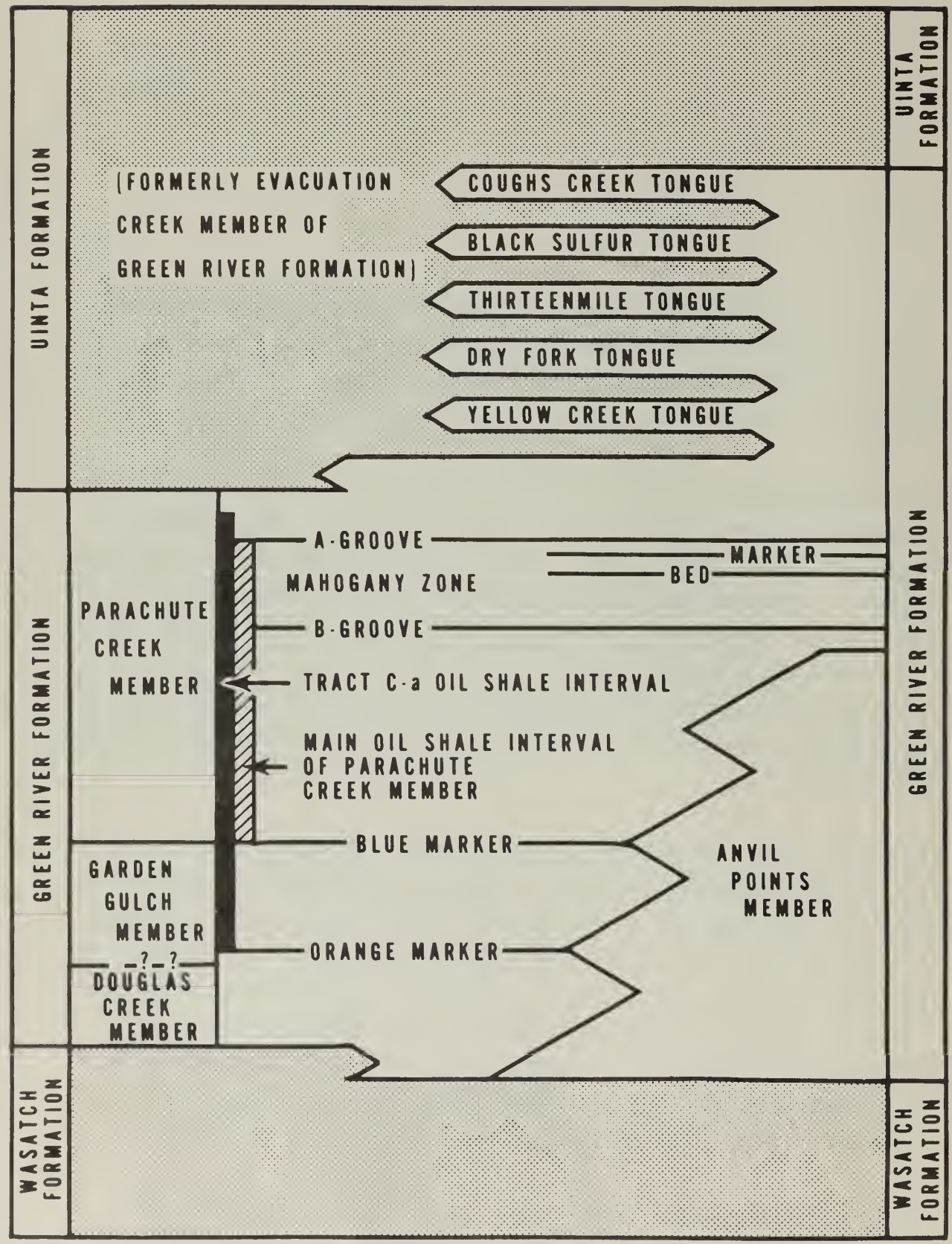


Figure 2-3-1

GENERALIZED STRATIGRAPHIC COLUMN OF TERTIARY EOCENE SERIES,
PICEANCE CREEK BASIN

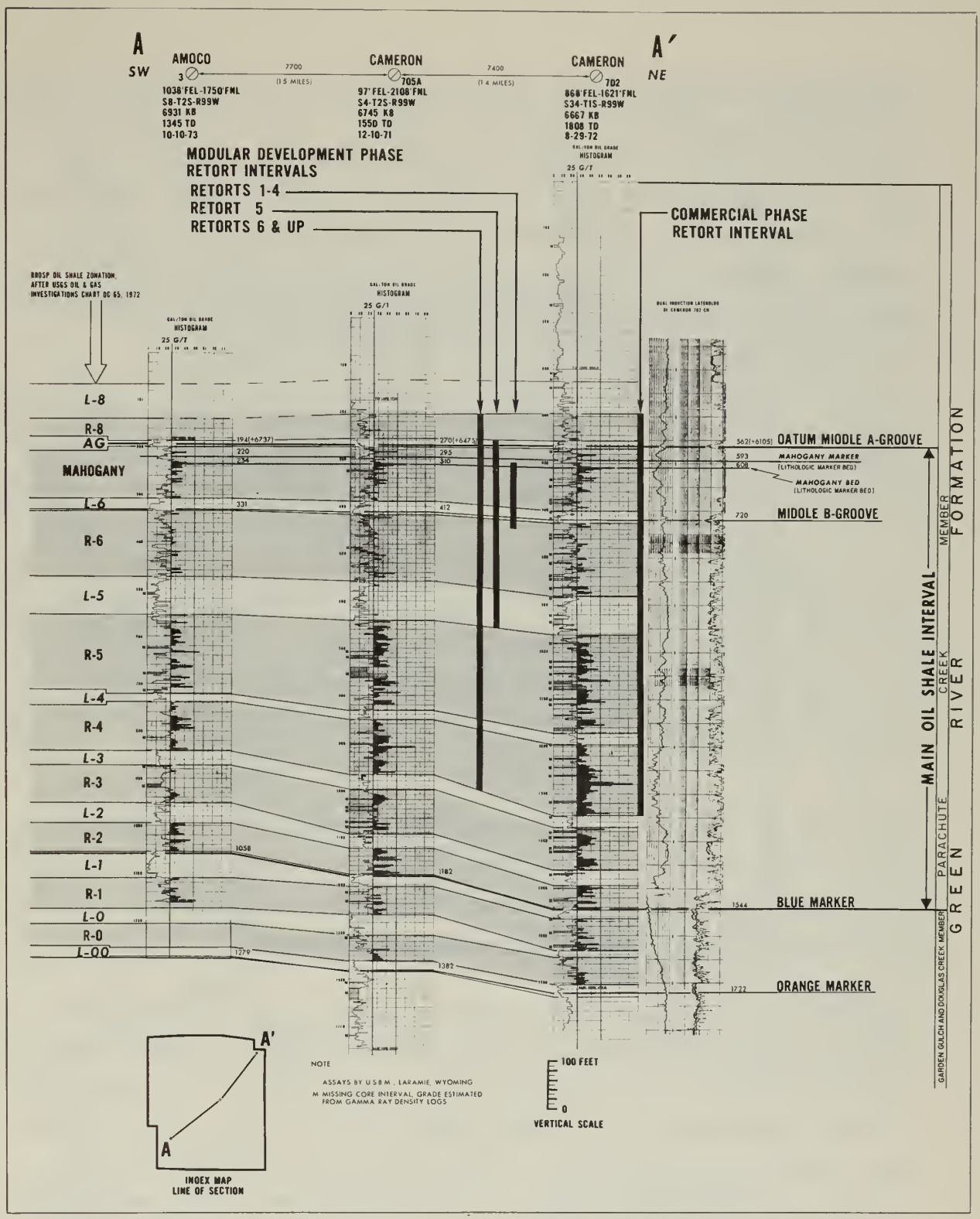


Figure 2-3-2

SW-NE 3-CORE HOLE HISTOGRAM CROSS SECTION, TRACT C-a

established by the USGS within the main oil shale interval (A-groove to Blue marker) on a regional correlation basis. The Rio Blanco zonation expands the USGS zonation stratigraphically above and below the main oil shale interval resulting in 19 zones, 9 relatively rich and 10 relatively lean. These zones are designated L-00 through L-8 in stratigraphically ascending order with the relatively rich and lean zones designated "R" and "L", respectively. The Mahogany and A-groove (AG) zonal nomenclature is retained because of their well established usage.

Dawsonite occurs mainly in the stratigraphic interval from the upper part of the R-2 zone through the lower part of the R-5 zone. Nahcolite is present in many of the oil shale zones but only in very minor quantities.

B. Structure - Figure 2-3-3 portrays Tract C-a structure based on photogeologic, surface geologic and subsurface core hole and off-tract well control. The horizon mapped is the middle of the A-groove, the electric log marker defining the top of the main oil shale interval of the Parachute Creek Member as shown on the cross section of Figure 2-3-2.

Tract C-a is located on the west flank of the Piceance Creek basin. Beds within the tract strike generally to the north and dip basinward to the east and northeast at an average rate of 200 to 350' per mile ($2\text{-}4^{o}$) except where locally disturbed by folds and faults.

The structural framework of Tract C-a is dominated by the southeast-plunging Sulfur Creek anticlinal nose and three major en échelon fault systems (graben) on its northeast flank. The trends of these graben are parallel-subparallel to the Sulfur Creek anticlinal axis. The northern-most graben is the most structurally complex of the three with fault displacement at the surface of up to 237'. Four minor folds and multiple subsidiary faults complete the structural framework. All faults as observed at the surface are high-angle to vertical.

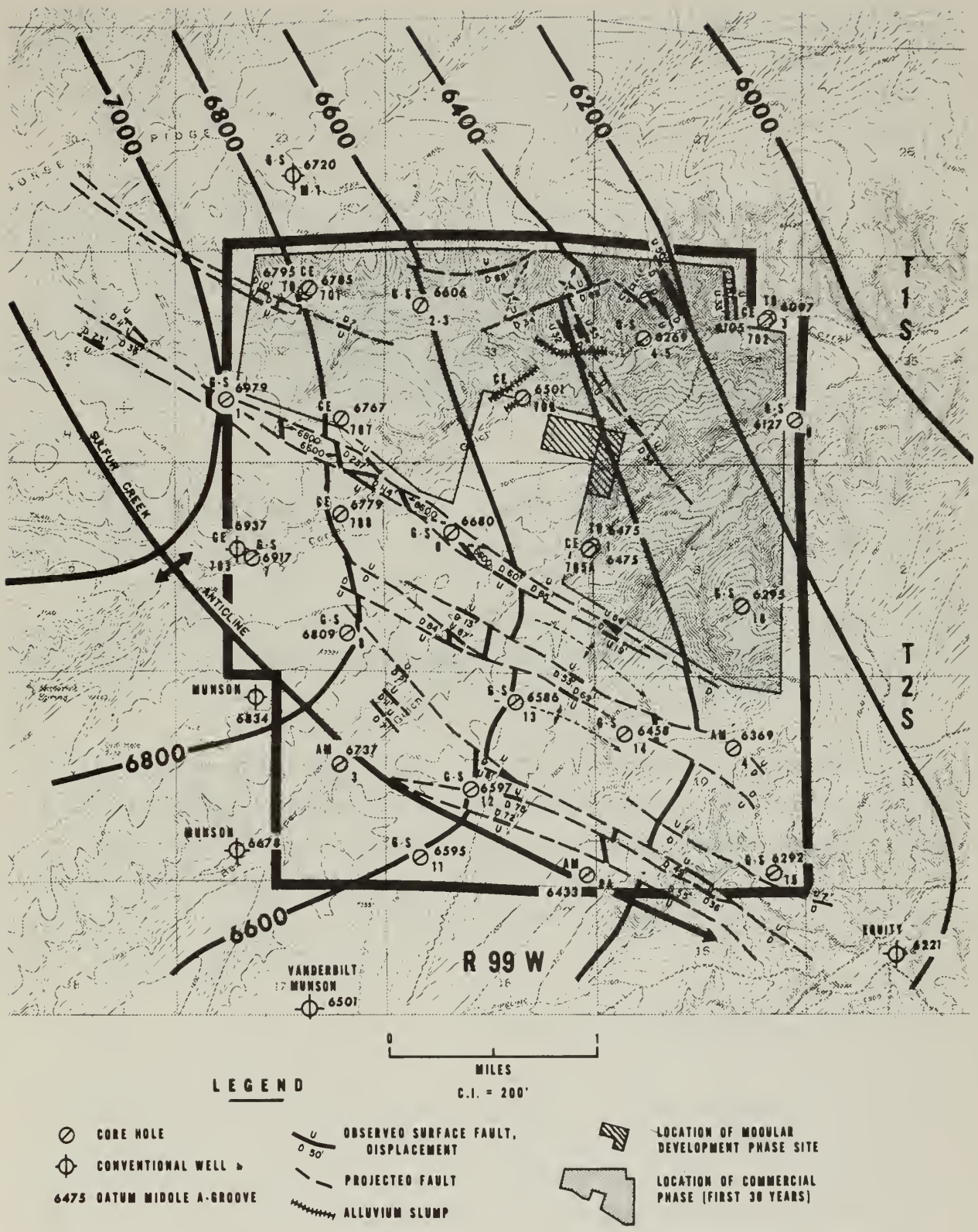


Figure 2-3-3

TRACT C-a MIDDLE A-GROOVE STRUCTURE MAP

Analysis of joint orientation data at 42 outcrop locations indicates a joint system consisting of three main sets is present within Tract C-a with joints in each set generally spaced 10' or more apart. For the entire tract, the average orientation of each set is as follows:

- The dominant set strikes N56°-76°W with dips of 74°SW passing through vertical to 86°NE. The set essentially parallels the axis of the Sulfur Creek anticlinal nose and the three en échelon graben on its northeast flank.
- The secondary set strikes N28°E with a dip of 80°NW.
- The tertiary set strikes N15°W with a dip of 75°E.

It should be stressed that the above joint orientations are average values for the entire tract. Some variations to these values occur locally thoroughout the tract.

Supplementing the above surface joint data, analysis of seisviewer log data in 12 on-tract holes indicates the following general joint orientations and frequencies in the subsurface:

- The joints are widely spaced, strike either northeast or northwest and primarily dip at angles greater than 60°.
- The number of joints tends to decrease with depth.
- Lean zones tend to have slightly more joints per foot of thickness than the rich zones.

3.2 MODULAR DEVELOPMENT PHASE (MDP)

A. Stratigraphy - Shown on Figure 2-3-2 are the various stratigraphic intervals which will be developed in the MDP. Retorts 1 through 4 will be confined to a 140' thick interval in the Mahogany, L-6 and R-6 zones. Retort 5 will encompass a 400' thick interval from about the top of the AG zone (A-groove zone) to the base of the L-5 zone. Retorts 6 and up

will encompass a 750' thick interval from the top of the R-8 zone to the base of the R-4 zone. This latter stratigraphic interval corresponds to that selected for the following Commercial Phase.

Retorts 1 through 5 will bottom above the dawsonitic shale interval (upper R-2 zone through lower R-5 zone). Retorts 6 and up will contain dawsonitic oil shale in their lower portions.

B. Structure - The location of the MDP site is shown on Figure 2-3-3. Beds strike N20^{o}W and dip gently basinward to the ENE at the rate of about 350' per mile (3-4^{o}). No faults are in near proximity to the site.

In the northeast part of Tract C-a, a joint system consisting of three joint sets is present. The main orientation of each set is as follows:

- The dominant set strikes N40^{o}W and dips 80^{o}NE.
- The secondary set strikes N47^{o}W and dips 65^{o}SW.
- The tertiary set strikes N65^{o}E and dips 85^{o}SE.

For maximum stability of the retort pillars, the long axis direction of the retort should be oriented normal to the strike of the dominant joint set or N50^{o}E. However, underground mining experience has shown that some leeway is allowable to minimize the operational slope of mining drifts. Toward that end, a N10^{o}E orientation for the long axis direction of the retorts was selected.

3.3 COMMERCIAL PHASE

A. Stratigraphy - As shown on Figure 2-3-2, the Commercial Phase retort interval is from the top of the R-8 zone to the base of the R-4 zone. This stratigraphic interval thickens basinward to the northeast across the tract from about 700' in the southwest corner to 850' in the northeast corner. Within the area outlined on Figure 2-3-3 for the

first 30 years of commercial operation, the interval's thickness ranges from about 720 to 850'. The lower portion of this interval contains dawsonitic oil shale.

B. Structure - Figure 2-3-3 shows the area selected for the first 30 years of the Commercial Phase. The area is located north of the northernmost graben with its southern boundary a minimum of 200' from the graben as a "buffer" or safety zone. Its other boundaries are controlled by the Tract C-a border.

Beds within the area strike generally N20^{o}W and dip gently basinward to the ENE at a rate of about 200 to 350' per mile (2-4^{o}) except where locally disturbed by faults.

Several faults are present within the area, most of which have displacements at the surface of less than 50'. Very likely, displacements as observed at the surface along these faults diminish with depth in the subsurface (typical of tensional faults) and most of the faults probably die out before reaching the oil shale zones. Direct evidence of this occurring is present in the northeast corner of the tract. There, faults with up to 50' of displacement at the surface mapped in the Uinta Formation die out before reaching the underlying upper Parachute Creek Member exposed in the canyon walls.

However, two faults mapped in the Uinta Formation in the north-central part of the tract exhibit displacements at the surface of almost 90' together with erratic dips, slump and distorted bedding (fault drag?). It is not known whether these faults are essentially confined to the Uinta Formation like those in the northeast corner of the tract, or extend to an appreciable degree into the underlying Parachute Creek Member and its oil shale zones. As retorts are developed in the vicinity of these two faults, caution will be exercised as mining drifts approach them.

The joint system discussed previously for the Modular Development Phase is applicable also to the Commercial Phase.

CHAPTER 4
HYDROLOGY

Presented in this chapter are general hydrological data for Tract C-a, and the Modular Development and Commercial Phases of the Modified In Situ retorting project. More detailed hydrology is provided in the RBOSP Quarterly Progress Reports on file in the office of the Area Oil Shale Supervisor, Grand Junction, Colorado.

4.1 TRACT C-a

A general description of Tract C-a hydrology encompasses the following:

A. Streams - All Tract C-a streams are classified as intermittent. However, some reaches are perennial, that is, certain sections of a stream have a continuous surface flow while others do not. See Figure 2-4-1.

Tract C-a has two perennial flowing stream reaches with one located in Corral Gulch and one located in Box Elder Gulch about 1/2 to 1-1/2 miles downstream from the tract's west boundary. The average flow in Corral Gulch is about 1/5 cfs and contains about 750 mg/l dissolved solids. The average flow leaving Tract C-a is slightly greater than 1/2 cfs and averages more than 800 mg/l dissolved solids.

B. Alluvial Aquifers - An alluvial monitoring program of observing water levels in drill holes showed water-saturated alluvium in Corral Gulch, Box Elder Gulch and the lower portion of Dry Fork near its confluence with Corral Gulch. In the other drainage systems, monitoring showed the alluvium to be dry. See Figure 2-4-2.

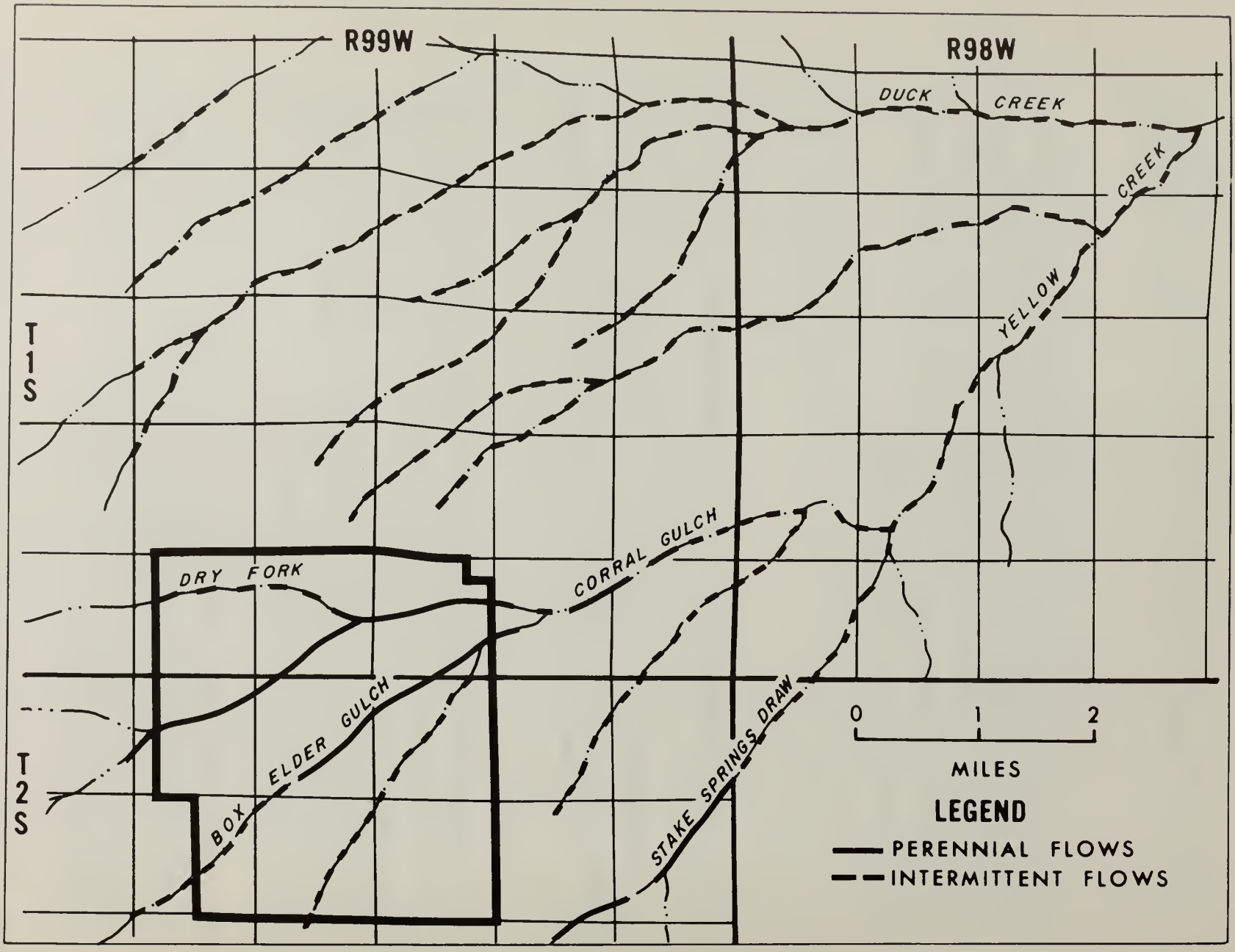


FIGURE 2-4-1

INTERMITTENT and PERENIAL STREAMS

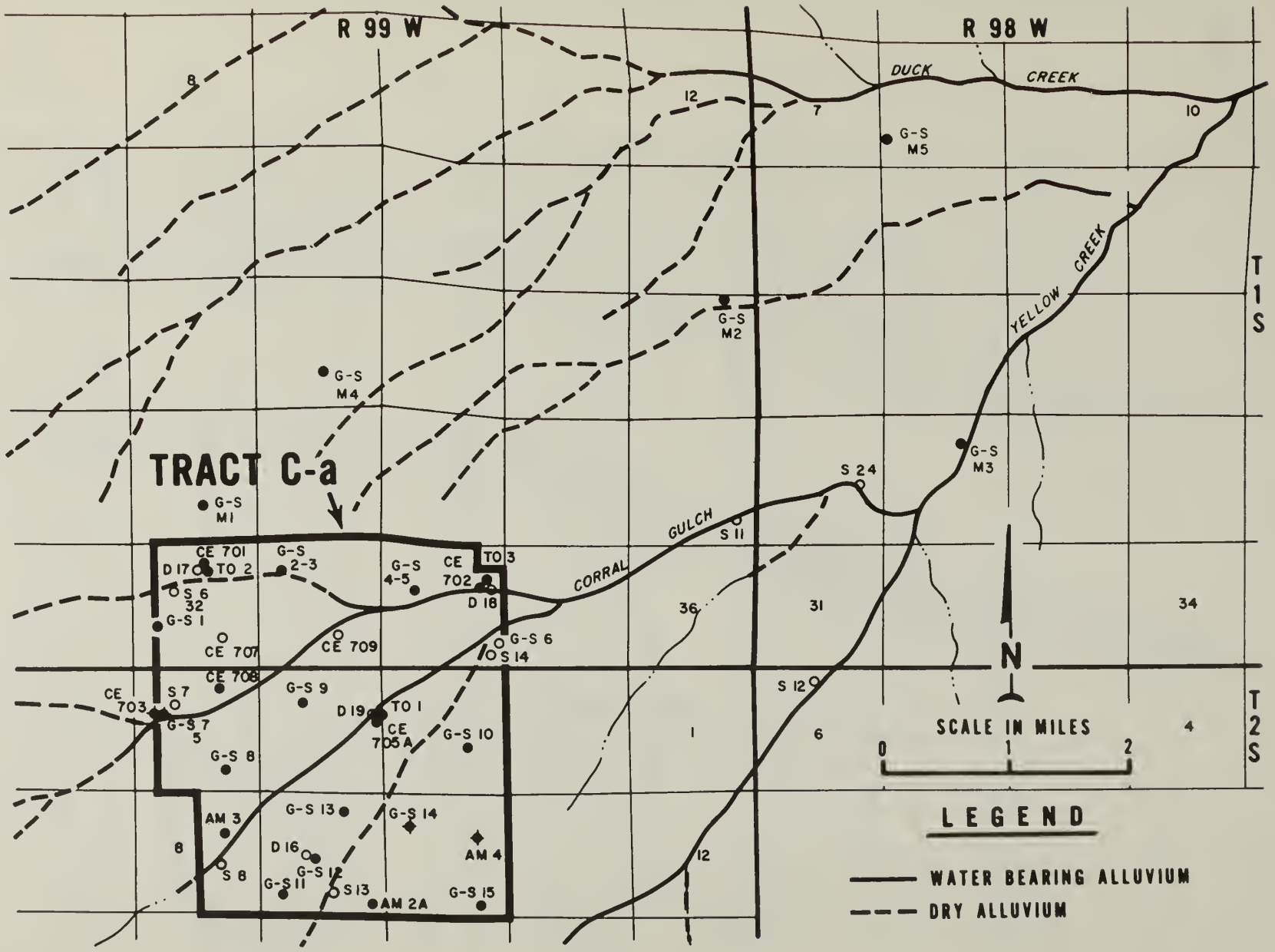


Figure 2-4-2
ALLUVIAL MAP TRACT C-a AND VICINITY

Monitoring of water levels in saturated alluvium shows that the level rises during snowmelt runoff and declines during remainder of the year.

Data, to date, indicate that the alluvial aquifers only respond indirectly to regional and local precipitation events.

Water quality in the alluvium tends to be poorer than water quality of the surface stream. On Tract C-a, the dissolved solids average approximately 900 mg/l for alluvium.

No pumping tests have been performed in the alluvium and therefore, related aquifer characteristics are relatively unknown. However, it is anticipated from the nature of the alluvial material that the permeabilities and porosities would be relatively low. Also, pumping tests on the deep oil shale aquifers did not indicate any measureable hydraulic connection between the alluvial aquifers and the deep oil shale aquifers.

C. Deep Oil Shale Aquifers - Various drilling programs indicate two major oil shale aquifer systems below the surface of Tract C-a. The upper system occurs generally within the Mahogany zone. The lower system is primarily associated with the R-3 zone, however, in some cases it extends down to the Blue marker. Thicknesses of the two aquifers, despite some wide fluctuations, average about 225 feet each. Both aquifers are artesian. See Figure 2-4-3.

Transmissivity values for the two aquifers were extrapolated from various pumping test data and are estimated at 2500 gpd/ft. and 7000 gpd/ft., respectively, for the upper and lower aquifers. Based on response to tests, it is concluded that the transmissivity and coefficients of storage for the lower aquifer system are much more reliable than those for the upper aquifer system.

Various pumping tests in both aquifer systems indicate an elongated drawdown cone of depression oriented with its long axis bearing NNW-SSE.

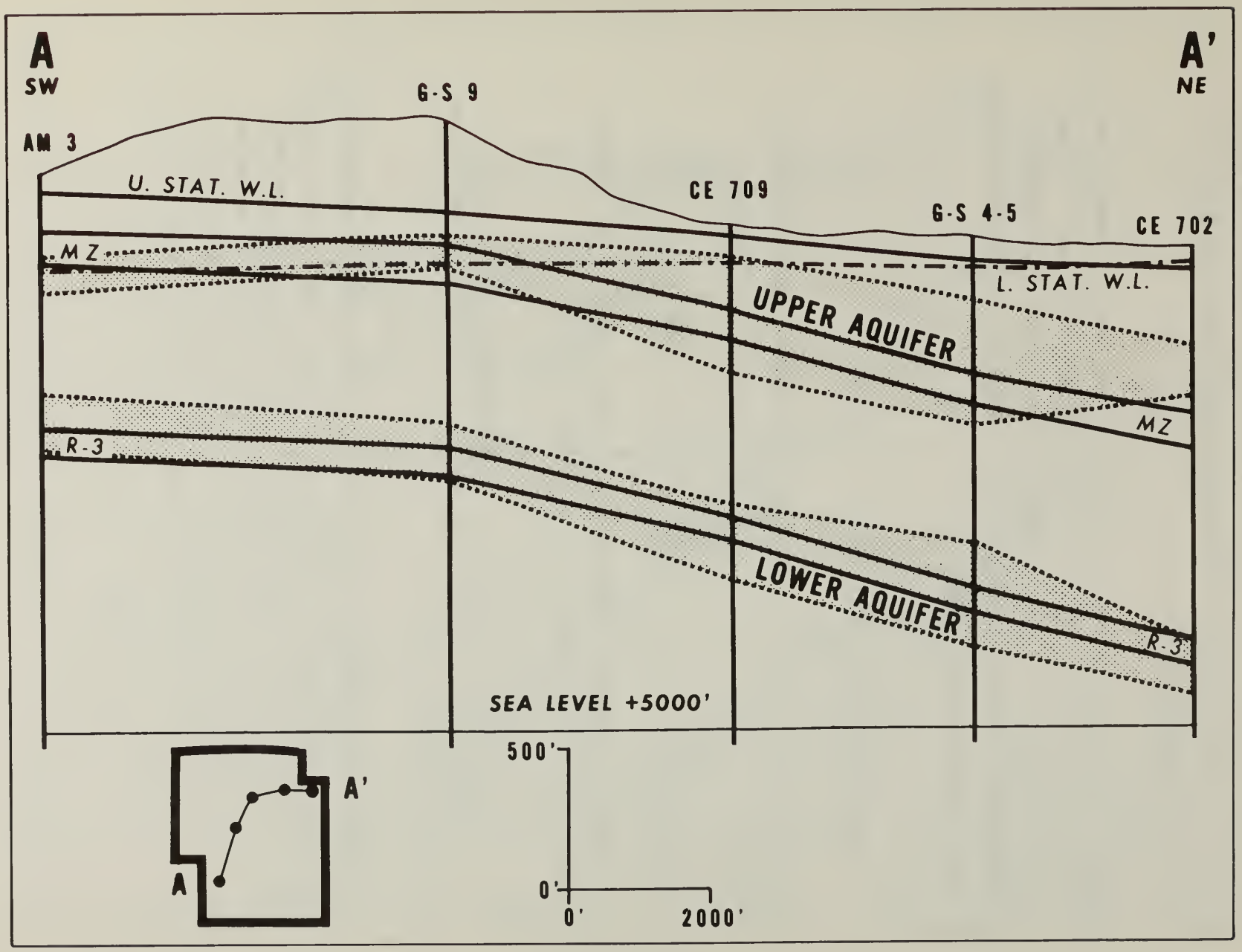


Figure 2-4-3

SW-NE CROSS SECTION SHOWING THE AQUIFER LOCATIONS

This bearing indicates the preferential direction of water flow is sub-parallel to the orientation of the major fracture-joint set that is identified throughout Tract C-a.

Concerning the effects of faults on the aquifers, various pumping tests indicate that the faults act as barriers and restrict flow in the upper aquifer but do not interrupt or affect the flow in the lower aquifer. This phenomenon suggests that the faults die out with depth, as discussed previously under Geology (Chapter 3).

4.2 MODULAR DEVELOPMENT PHASE (MDP)

Hydrology considerations for the Modular Development Phase include the following:

A. Precipitation - Annual precipitation is typically 10-17 inches.

B. Springs and Seeps - There are no springs or seeps in the proximity of the Modular Development Phase. See Figure 2-4-4.

C. Streams & Alluvial Aquifers - Hillside placement elevates the MDP above and away from stream beds and alluvial aquifers. See Figures 2-4-1 and 2-4-2.

D. Deep Oil Shale Aquifers - Vertical positioning places the Modular Development Phase underground workings in the upper aquifer and in the upper fringes of the lower aquifer. Most of the underground workings, with the exception of a few isolated openings (shafts), lie above the bottom of the R-4 zone while the main portion of the lower aquifer is confined to the R-3 zone (below the R-4). See Figure 2-4-3.

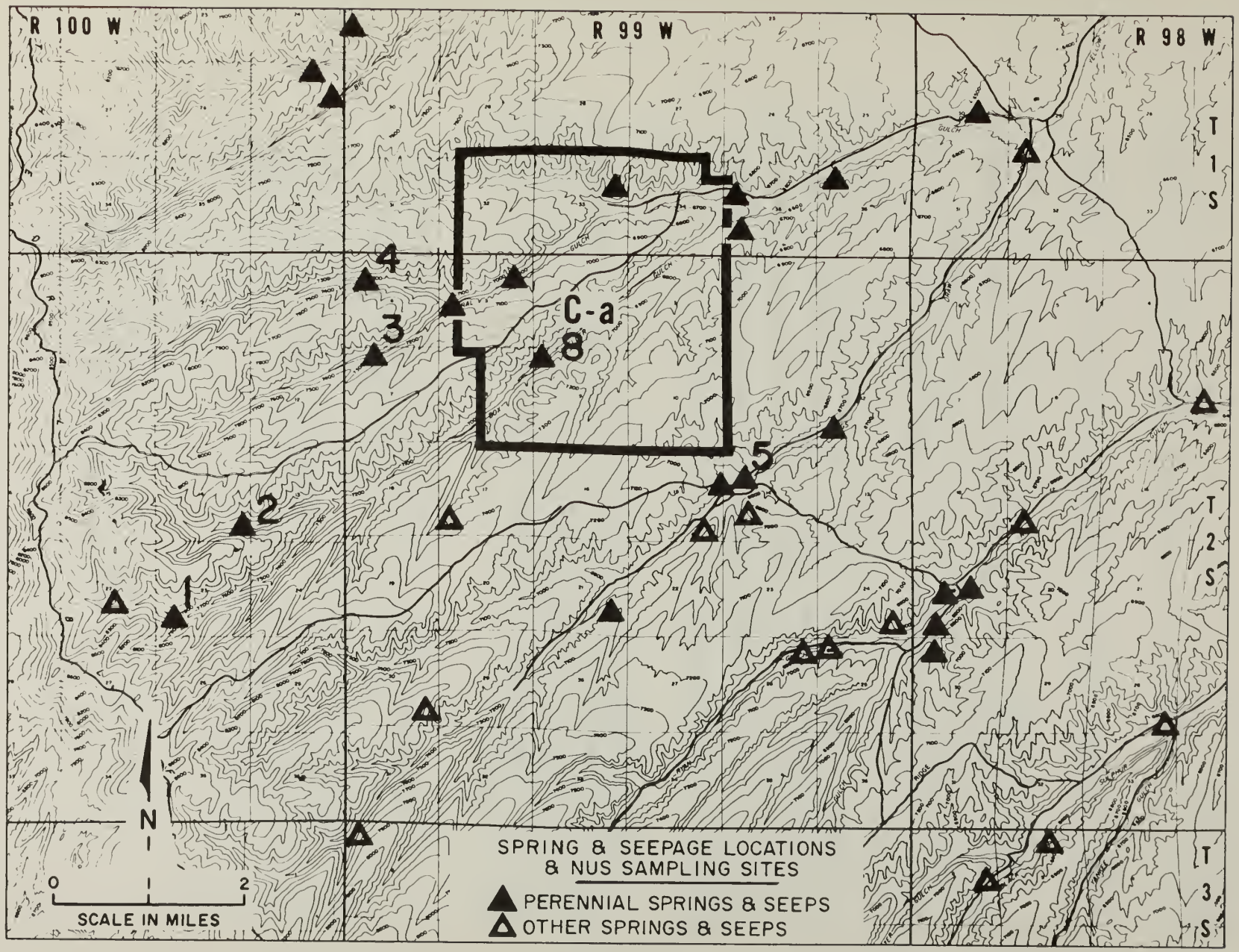


Figure 2-4-4
SPRING AND SEEPS INVENTORY

4.3 COMMERCIAL PHASE

Hydrology considerations for the Commercial Phase include the following:

A. Precipitation - Annual precipitation is typically 10-17 inches.

B. Springs and Seeps - Only one seasonal spring lies within the combined surface boundary limits of the Commercial Phase mine surface facilities and underground workings. This spring is located in Dry Fork near its confluence with Corral Gulch. See Figure 2-4-4.

C. Streams - The previously described perennial flowing stream reaches located in Box Elder Gulch overlap a portion of the Commercial Phase underground workings. The perennial stream in Corral Gulch enters the subsurface (alluvium) before reaching the boundary of the Commercial Phase. See Figure 2-4-1.

D. Alluvial Aquifers - Saturated alluvium within the boundary of the Commercial Phase occurs in Box Elder Gulch, Corral Gulch and the lower end of Dry Fork near its confluence with Corral Gulch. Additional details for these alluvial aquifers are provided in section 4.1 of this chapter. See Figure 2-4-2.

E. Deep Oil Shale Aquifers - Vertical positioning places the Commercial Phase underground workings in the upper aquifer and also in the upper fringes of the lower aquifer. Most of the underground workings, with the exception of a few isolated openings, (shafts and product return drifts) lie above the bottom of the R-4 zone, while the main portion of the lower aquifer is confined to the R-3 zone. See Figure 2-4-3.

CHAPTER 5
ROCK MECHANICS

5.1 TRACT C-a

A comprehensive rock mechanics program was initiated during the RBOSP, Tract C-a exploration phase for the purpose of establishing some basic rock mechanics parameters that could be used effectively in future mine design work. Through testing and interpretative work, this program was successful in developing key parameters considered essential for acceptable mine design work. Of these design parameters, a major portion was derived from data generated by laboratory tests run on core samples obtained from drill-holes G-S (Gulf-Standard) 2-3, 4-5, 6, 11, 13 and 15; however, a few parameters related to rock mechanics were developed from other sources.

A. Static Rock Properties - Laboratory tests on drill-hole core identified and quantified basic rock properties that were used to establish various design parameters. A listing of the rock properties developed from the core testing is as follows:

- Uniaxial compressive strength
- Modulus of elasticity
- Tensile strength
- Angle of internal friction
- Cohesion
- Rock density
- Shear strength
- Modulus of rupture
- Poisson's ratio
- Shear strength of rubble material

Concerning the preceding rock properties; laboratory test results for uniaxial compressive strength, modulus of elasticity, tensile strength, angle of internal friction and modulus of rupture were correlated with ore grade, irrespective of zone. In addition, the same type of tests and correlations were made for only the Mahogany zone. These test results and correlations are illustrated by individual graphs included in the Confidential Volume of this DDP.

Additional explanation of the listed rock properties is provided by the following:

- Uniaxial Compressive Strength - The uniaxial compressive strength of oil shale has been shown in the past to be directly related to oil content. Compressive strength decreases with an increase in oil content. It is noted that compressive strength, irrespective of zone on Tract C-a, appears to be generally lower than the compressive strength of the Mahogany zone at Anvil Points and Colony Mines. Also, the Mahogany zone compressive strength appears to be higher than the case where all zones are considered. In all cases, compressive strength appears to become constant in the range of 34 to 40 GPT.

  Reason for the apparent difference between rock strength and ore grade by zone and irrespective of zone is not known. The difference may be related to the detailed mineralogy of the various mining horizons which contain varying amounts of nahcolite and dawsonite as well as various clay minerals.

  A comparison of oil grade and compressive strength for the Mahogany zone and all possible mine zones on Tract C-a is illustrated in the Confidential Volume of this DDP.

- Modulus of Elasticity - The modulus of elasticity also decreases with increasing oil content between 0 and 45 GPT. The modulus of elasticity values for Tract C-a were plotted irrespective of zone. Sufficient data were not available for determination of the ore grade-modulus relationship by zone except for the Mahogany zone, where the modulus of elasticity tends to be higher than in the case where all zones are considered.

  It is noted that the modulus of elasticity for all zones at Tract C-a is significantly lower than it is for the Mahogany zone at Anvil Points. The reason for this apparent difference is not known, but as in the case of the compressive strength, the difference is possibly related to mineralogy.

  A comparison of oil grade and modulus of elasticity is shown in the Confidential Volume.

- Tensile Strength - Tensile strength was determined by Brazilian tests of core samples. Tensile strength appears to increase with oil content between 0 and 28 GPT. At approximately 28 GPT, tensile strength values become almost constant.

  A comparison of oil grade and tensile strength is shown in the Confidential Volume.

- Angle of Internal Friction - Intact Rock - Sufficient data are available to correlate oil content with the angle of internal friction for intact rock in the range between 10 and 45 GPT. This angle ranges from near 43^{o} for 10 GPT to 25^{o} for 45 GPT.

  A comparison of oil grade and angle of internal friction is shown in the Confidential Volume.

- Angle of Internal Friction - Rock Joints - Tests on rock samples containing planes of weakness are limited. The results indicate that the strength of jointed rock is quite high, possibly in the general range of intact or unjointed rock. The average coefficient of sliding friction, as determined by tests, is about 0.7 or an angle of internal friction of 35^{o} for both open and sealed joints.

- Cohesion - The limited testing of Tract C-a rock samples containing sealed joints indicates cohesion may average about 250 psi.

- Density - The relation between oil content and grain density has been well established by investigators in the Piceance Creek basin. The best known curve for oil content-density is the John Ward Smith curve developed by the U.S. Bureau of Mines. From density determinations of Tract C-a core, it was found that a modification of the John Ward Smith relationship gave a better data fit to Tract C-a conditions. This curve is explained in detail in the Confidential Volume.

- Shear Strength - No definite relationship has been established between oil content and shear strength of Tract C-a oil shale. Laboratory test values from triaxial tests were found to range from 2505 to 3950 psi. The average value from direct shear tests for the peak shear strength of intact samples is as high as 2350 psi.

- Modulus of Rupture - On Tract C-a the modulus of rupture has proved to be 3 to 4 times the tensile strength.

  A comparison of oil grade and modulus of rupture is shown in the Confidential Volume.

- Poisson's Ratio - Testing has shown Poisson's Ratio to be independent of oil content and highly dependent on stress levels during testing.

- Rubble Strength - Preliminary shear strength of rubble prior to retorting was tested in triaxial compression on samples with a maximum range of one inch, and this gave friction angle values of approximately 30^{o}. After retorting, but not under compression, similar tests were conducted. These gave friction angles which proved lower. Both series of tests provided non-linear failure envelopes.

B. Dynamic Elastic Properties - The preceding properties which have been established for oil shale are all static properties. In order to determine in situ elastic properties utilizing Birdwell borehole velocity logs, a number of dynamic tests were performed on core samples to establish a ratio between the static and dynamic elastic properties. The ratio of static to dynamic modulus of elasticity generally increases with depth and the ratio of static to dynamic Poisson's ratio generally decreases with depth. As expected, the dynamic elastic constants are greater than the static elastic constants. Where no in situ measurements are available, the in situ static modulus of elasticity and Poisson's ratio were assumed to be 0.43×10^{6} psi and 0.37, respectively, for the Mahogany zone.

C. In Situ Rock Characteristics - Information regarding the in situ rock characteristics was obtained from rock joint data on outcrops, seisviewer logs and core logs. From these sources, the nature, number and orientation of major joints were determined to the extent possible. The in situ rock stresses were utilized from published information on hydrofracture tests made by the U. S. Geological Survey in pre-lease drill-holes CE 702 and CE 703.

D. Structural Geology - Initially, the structural geology of the tract was reviewed to determine the relationship between major structural

features and potential underground mine locations. Major structural features include the Sulfur Creek anticline and the three major graben (fault systems), which trend northwest across the tract. Additional subsidiary faulting and folding have also been mapped within the tract. For all studies to date, all surface faults have been assumed vertical in the subsurface based on their orientations at the surface. The displacements on each fault as observed at the surface were assumed to extend through the entire depth of the orebody. However, very likely, these displacements diminish with depth and the faults eventually die out.

The geologic structure of the tract is related to the in situ stress present within the Piceance Creek basin. During a study of the groundwater hydrology in the northern portion of the basin, the USGS determined the regional state of tectonic stress in Tract C-a. From hydraulic fracturing experiments, it was determined that the primary horizontal stress is acting in a N75^{O}W to S75^{O}E direction and the secondary horizontal stress is acting N15^{O}E to S15^{O}W. The magnitude of the maximum horizontal stress was determined to be equal to 0.95 of the overburden stress.

Other structural features studied throughout the tract are the natural rock joints. Joints were mapped at 42 outcrop stations across the tract. Subsurface joints defined by Birdwell seisviewer logs were also reviewed.

5.2 MODULAR DEVELOPMENT PHASE (MDP)

All preceding material concerning rock properties presented for Tract C-a is applicable to the Modular Development Phase site. For site specific structural geology, refer to Chapter 3, Geology, of this Section, and for application of rock mechanics to mine design refer to Chapter 6, Mine Design, of this Section.

During the Modular Development Phase, a rock mechanics program will be implemented to validate the modular development and commercial design. This will include the following:

- Detailed structural geological mapping of accessible shafts, and underground openings.

- Determination of in situ or virgin stresses using two types of overcoring methods. (Overcoring - refers to isolating a segment of in-place rock by drilling a circular ring around the rock to some prescribed depth.)

- Determination of rock mass strength to be performed on medium and large-scale samples in situ. The results will be correlated with previous laboratory test results.

- Determination of actual stresses and strains in the pillar during the whole mining and retorting process.

- Determination of roof stability by use of multiple point extensometers and correlation with surface subsidence.

- A determination of the loads imposed by the rubble at the base of the retort.

- Monitoring of the effect of temperature on the pillars and investigation of the possible leakage of gas by pressurizing retorts prior to retorting.

5.3 COMMERCIAL PHASE

All preceding material concerning rock properties presented in 5.1 and 5.2 is applicable to the Commercial Phase. For site specific structural

geology refer to Chapter 3, Geology, of this Section, and for application of rock mechanics to mine design refer to Chapter 6, Mine Design, of this Section. As a result of the experience and data obtained in the Modular Development Phase, appropriate changes in the commercial design will be made. A continuing program of rock mechanics and geology will be undertaken to accommodate the variations in ground conditions which may be experienced.

CHAPTER 6
MINE DESIGN

6.1 GENERAL MINE ARRANGEMENT

As described in Chapter 2 of this section and illustrated by Figure 2-6-1, the underground mine areas for the Modular Development and Commercial Phases of the Tract C-a Modified In Situ (MIS) retorting project are located in the north half of the tract. More specifically, the MIS area is bounded on the south by the northernmost graben and on the east, north and west by the tract boundaries.

General mine arrangement includes four commercial retort fields with a central shaft pillar, five Modular Development Phase (MDP) retorts positioned in the east portion of the shaft pillar, and additional MDP retorts located adjacent to the shaft pillar in the west portion of Commercial Field No. 3. See Figure 2-6-1.

Placement of the shaft pillar in the south-central part of the MIS area was required to minimize the ore haulage distance between the mine and surface retorting facilities. Besides providing protection for six Commercial Phase and two MDP mine shafts, the pillar also protects combustion air compressors, a gas treatment plant and other facilities that are located on the pillar near the mine.

Sizing the shaft pillar was influenced by the possibility of ground subsidence occurring over abandoned burned-out retorts. To minimize the threat of damage to permanent surface facilities, the pillar was designed with 45^{o} slopes projecting outward and down from a perimeter line bordering the surface facilities to the sides of the retorts that border the pillar. For added protection against subsidence, retort rubblizing and burning sequences will be toward the shaft pillar. Therefore, if during retorting, subsidence does occur and exceeds the 45^{o} limit,

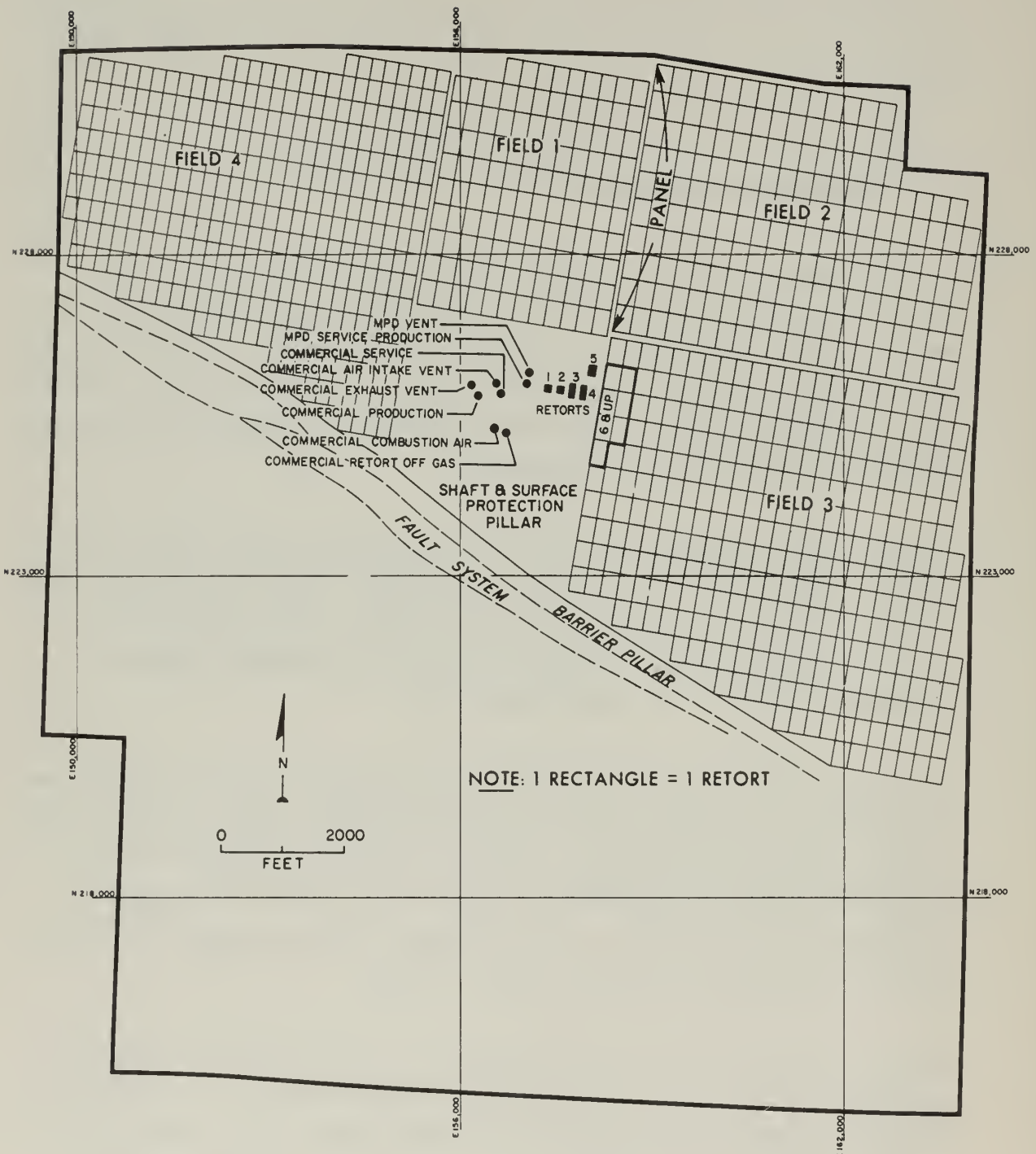


Figure 2-6-1

GENERAL TRACT LAYOUT

development in any given panel can be stopped sooner than planned. As a result, pillar protection for surface facilities can be maintained. Additional information on subsidence is in Chapter 8 of this section and Section 6, Chapter 13.

Mine layout of the Modular Development Phase within the shaft pillar includes a production-service shaft, exhaust ventilation shaft and five retorts, and outside the shaft pillar, additional retorts. Four of the five retorts inside the shaft pillar are positioned in a line that runs east from the shaft while the farthest away, fifth retort, is offset to the north of this line. These retorts are considerably smaller than commercial retorts and are graduated in size. Relative to the service-production shaft, the smallest retort is closest and the largest is furthest away. The larger MDP Retorts, 6 and up, are commercial-sized and are positioned adjacent to the east border of the shaft pillar in Commercial Field No. 3. See Figure 2-6-1.

The number of commercial-sized retorts to be burned during the Modular Development Phase is dependent on experience-factors derived from the operation of earlier retorts and on equipment and manpower availability. However, they are an integral part of the scheduling and sequencing phases of mine planning, though their number is not fixed.

Mine layout of the Commercial Phase includes six shafts located west of the MDP shafts within the shaft pillar; and four separate retort fields outside the pillar. The shafts are identified as service, production, intake ventilation, exhaust ventilation, retort offgas and combustion air. The retort fields include No. 1 north of the shaft pillar, No. 2 northeast of the pillar, No. 3 east of the pillar, and No. 4 northwest of the pillar. These fields will be developed in their numerical sequence.

6.2 MODULAR DEVELOPMENT PHASE (MDP)

The Modular Development Phase for the Tract C-a Modified In Situ retorting operation is designed to provide the means of systematically and incrementally

developing the operation from a small modular activity into a full-scale commercial operation. When implemented, the MDP will provide the experience and information necessary for improving operating efficiencies, evaluating capital and operating cost estimates, and identifying and correcting operating problems.

Basically, the plan for the MDP consists of burning individual retorts in a sequence that allows an evaluation of the previous burn before the next is started. Five various sized small retorts and several commercial-sized retorts are scheduled to be burned during the MDP. The smallest Retorts, 1 and 2, will be burned first; followed by the burning of the next larger Retorts, 3 and 4; followed by the burning of the next larger Retort, 5; and finally followed by the sequential burning of commercial sized Retorts, 6 and up. See Figure 2-6-1.

Preparation for burning these Modular Development Phase retorts will be accomplished by underground mining methods. Mining will provide access to the retorts through developed underground workings. Rubblizing of the smaller Retorts, 1 through 4, will be accomplished by specialized drilling and blasting techniques. Rubblizing of Retort 5 and the commercial-sized retorts will be accomplished by a sublevel caving mining method.

A. Access - Mine access for the Modular Development Phase includes one service-production shaft, one ventilation shaft and 10 sublevels. Four of the sublevels are connected to the shafts and the remainder are interconnected by ramps. See Figure 2-6-2 and 2-6-3.

1. Geometry - Modular Development Phase mine workings, with the exception of the shafts, are confined to the stratigraphic interval lying between the top of the R-8 zone and the bottom of the R-4 zone. See Section 2, Chapter 3, Figure 2-3-2. The network of shafts, sublevels and other underground workings is illustrated by Figure 2-6-2.

a. Service-Production Shaft - The service-production shaft is 15 feet in diameter, concrete lined and 1,185 feet deep. The design

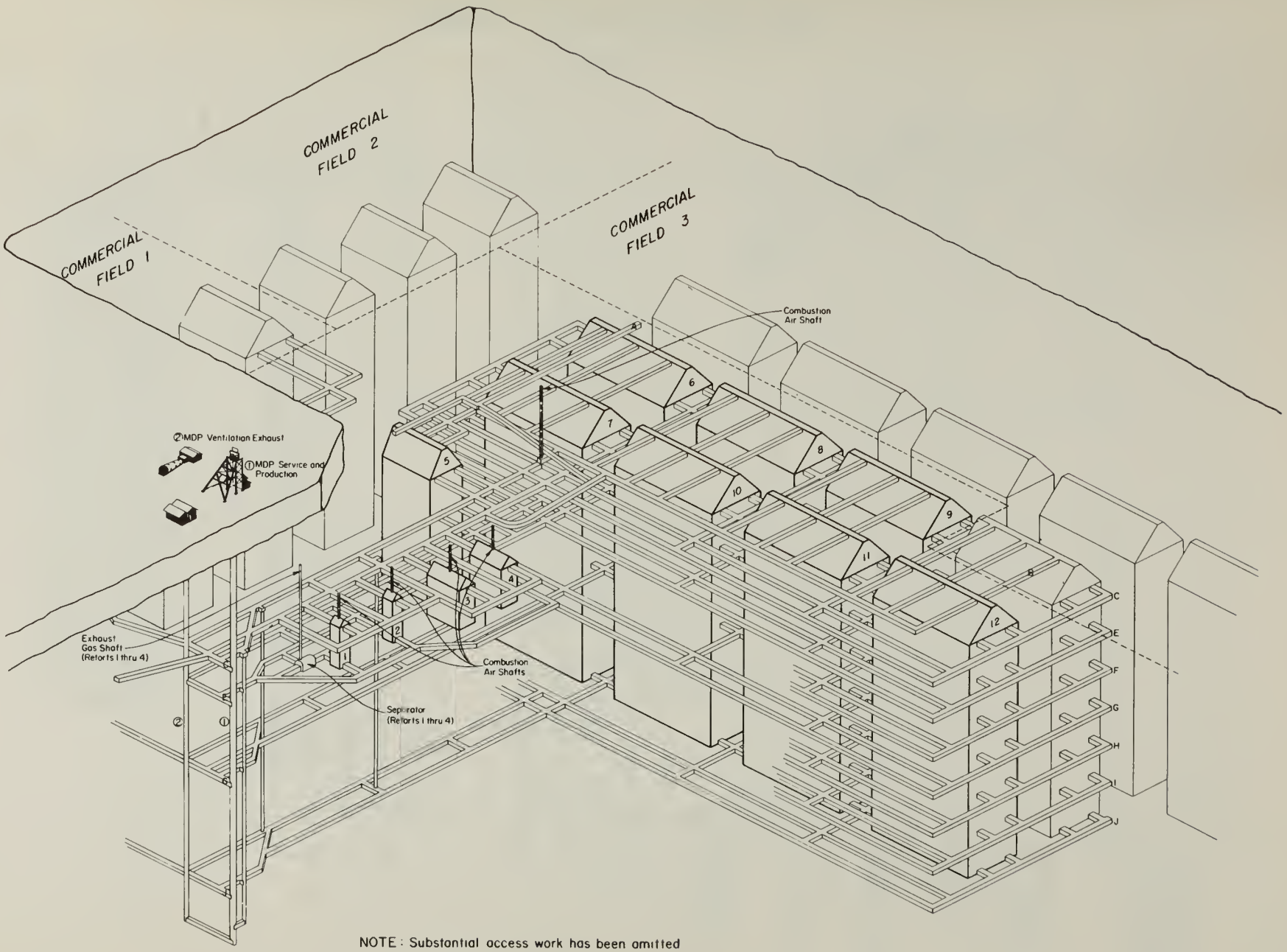

COMMERCIAL FIELD 1
COMMERCIAL FIELD 2
COMMERCIAL FIELD 3
②MDP Ventilation Exhaust
①MDP Service and Production
Combustion Air Shaft
Exhaust Gas Shaft (Retorts 1 thru 4)
Combustion Air Shafts
Separator (Retorts 1 thru 4)
NOTE: Substantial access work has been omitted in the interest of clarity.

Figure 2-6-2

MODULAR DEVELOPMENT PHASE - SCHEMATIC ACCESS LAYOUT

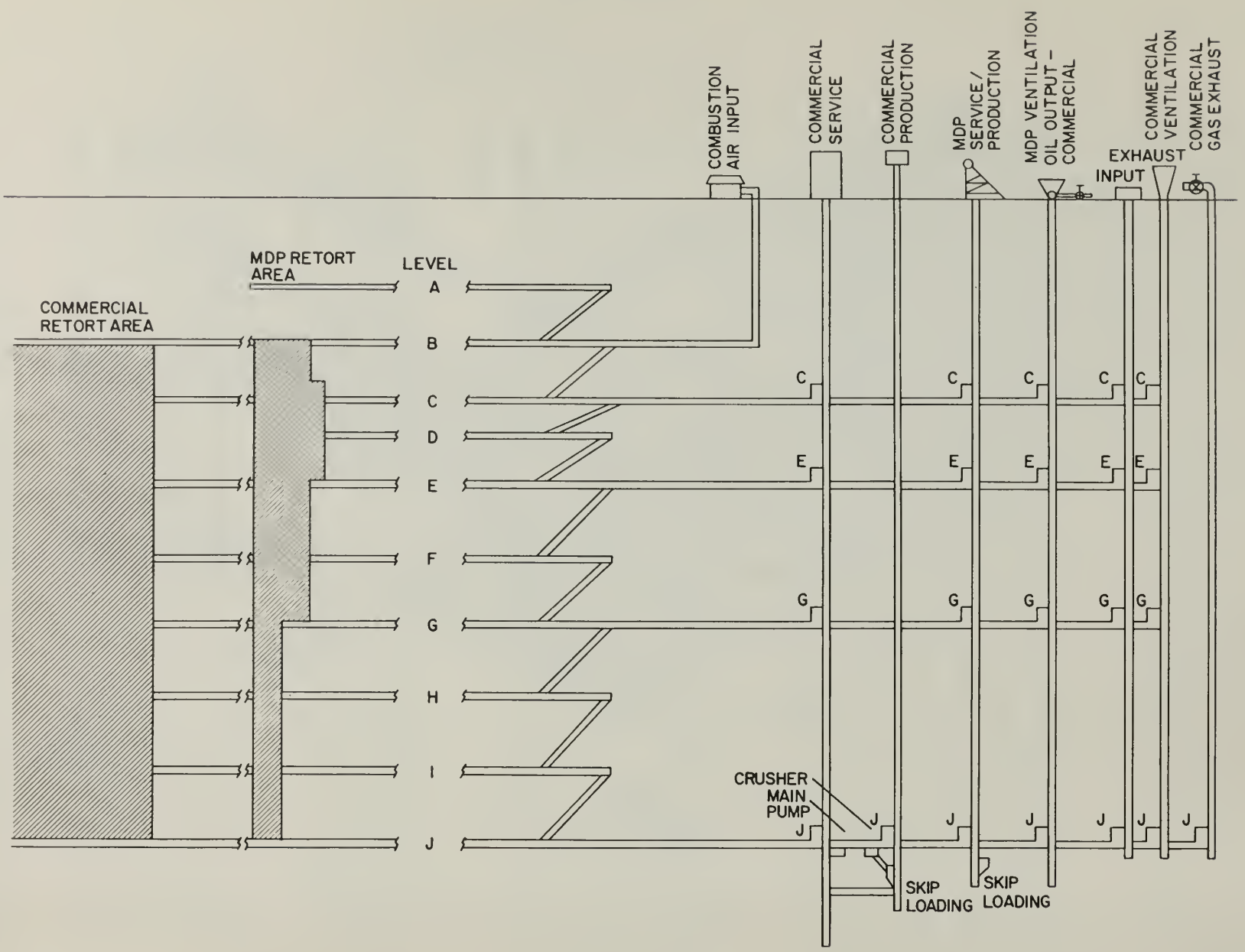


FIGURE 2-6-3

SCHEMATIC - SHAFT/LEVEL/RAMP LAYOUT

includes a ladderway and service lines (compressed air, drinking and fire water lines, pump mains, and power and communication cables). See Figure 2-6-3.

b. Ventilation Shaft - The ventilation shaft is 7 ft. in diameter, steel lined and 1,185 ft. deep. See Figure 2-6-3.

c. Sublevels - Ten sublevels (A through J) will be used to develop and monitor the Modular Development Phase retorts. The main entrance drift on each sublevel, the main haulage drifts ('J' level) and the ramps will be 15 ft. wide by 12 ft. high. All other drifts will be 13 ft. wide by 10 ft. high. See Figure 2-6-3.

2. Development Method - Development method refers to the means used to excavate the various mine openings.

a. Service-Production and Ventilation Shafts - The ventilation shaft will be drilled and the service-production shaft will be upreamed. These size shafts and the Tract C-a rock characteristics are well-suited for the proposed drilling and upreaming methods. Also, drilling and upreaming advance faster and cost less per foot than the conventional sinking method.

The development sequence includes: drilling the ventilation shaft to total depth and casing; driving a horizontal connection from the shaft bottom to the location of the service-production shaft; and pilot drilling and upreaming the service-production shaft. Development rock from the connection drift and service-production shaft will be hoisted up the ventilation shaft by temporary equipment. Following excavation, the service-production shaft will be lined with concrete and equipped from temporary staging using the permanent headframe and hoist. Level and skip stations, loading pockets and related facilities will be established during this phase.

b. Main Haulage and Sublevels - Following the initiation of shaft services, the levels will be extended. Initial development will include connecting the main haulage level and three sublevels to the ventilation shaft to establish air flow and an escape route. Subsequent development will be toward the first retort.

The drifting cycle will include drilling with a three-drill jumbo, shooting with ANFO, and loading and hauling with 5-cy load-haul-dump (LHD) units. Early development rock will be hauled directly to a rock-pass near the shaft which will deliver the rock by gravity directly to the skip loading station. As development progresses away from the shaft, additional rock-pass raises will be bored through all levels to the bottom main haulage level. On the main haulage level, each rock-pass will be equipped with a loading chute. Trucks will be loaded from the chutes and will haul the rock to the central rock-pass at the shaft station.

When possible, all drifts will be driven from the shaft on a slightly positive grade to ensure good drainage from the working face and road-bed. Because the drifts are relatively small (15 feet wide by 12 feet high and 13 feet wide by 10 feet high), no serious problems are anticipated from rock failures. However, rock bolting will be performed where needed.

B. Retort System - The retort system is sited as shown on Figure 2-6-1.

1. Geometry - The retorts range in height from 140' for Retorts 1 and 2 to about 700 feet for commercial size Retorts 6 and up. Retorts 1-4 are located in the Mahogany, L-6 and R-6 zones. Retort 5 is positioned in the interval from the A-groove to the base of the L-5 zone. Retorts 6 and up encompass the interval from the top of the R-8 zone to the base of the R-4 zone. See Figure 2-3-2.

a. Retorts 1 and 2 - These two retorts are the same size with horizontal dimensions of 30 feet by 30 feet, and height of 140 feet.

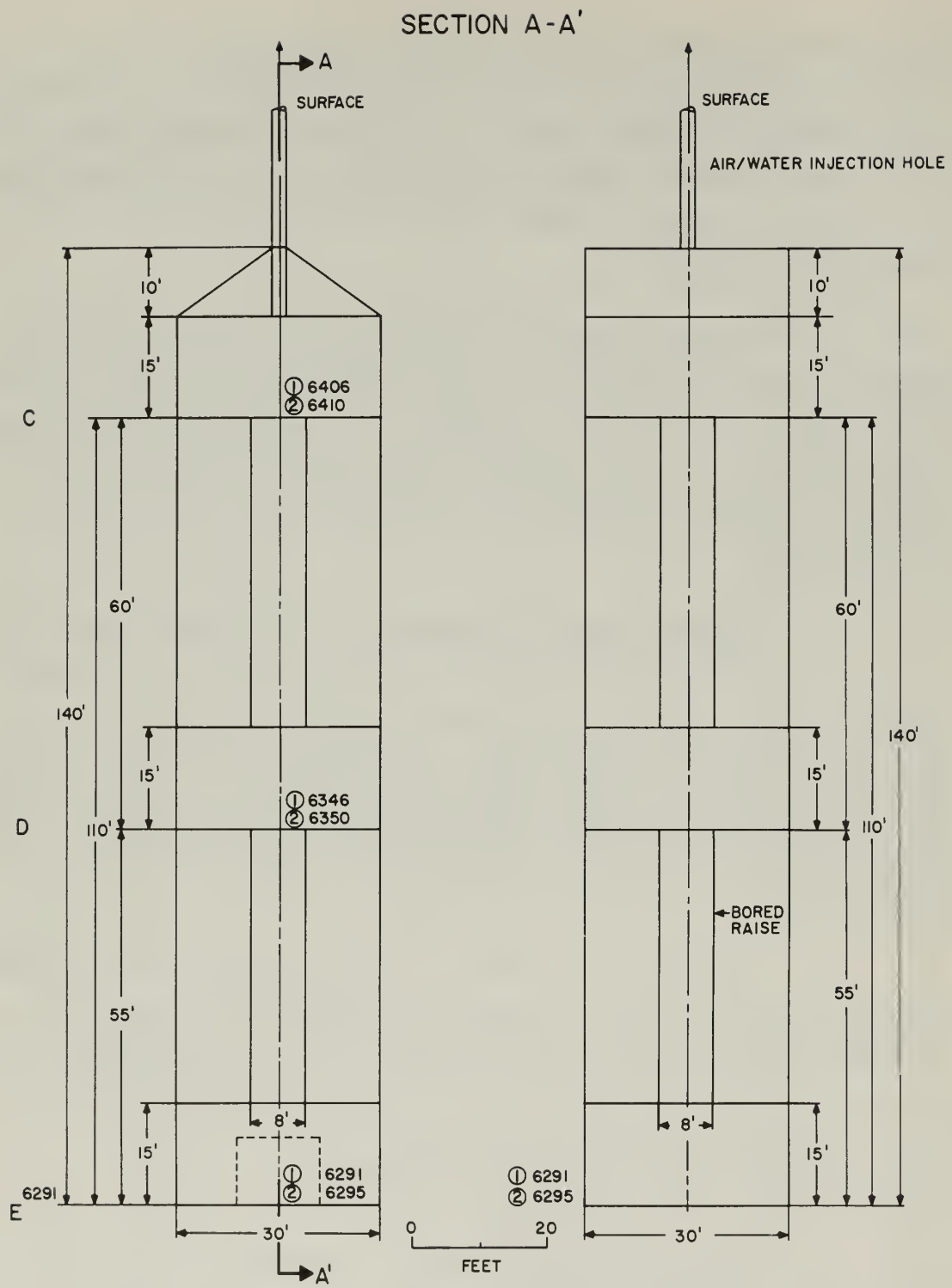
Their roof is arched for stability and the floor is flat. Access for development is at the top (C level), middle (D level) and the bottom (E level). A 48-inch diameter bored hole from surface to the arched roof will be used to inject combustion air. Retort 1 is positioned 290 feet from the shaft and separated from Retort 2 by a 130-foot pillar. See Figures 2-6-1 and 2-6-4.

b. Retorts 3 and 4 - These two retorts are the same size with horizontal dimensions of 50 feet by 100 feet and a height of 140 feet. Roof, floor, access and injection air arrangements are similar to those for Retorts 1 and 2. Retort 3 is separated from Retort 2 by a 100-foot pillar and from Retort 4 by a 75-foot pillar. See Figures 2-6-1 and 2-6-5.

c. Separator Room for Retorts 1-4 - A separator room, 18 feet wide by 80 feet long by 29 feet high will be developed to receive and separate retort products. The chamber is positioned north of, and at the bottom elevation of the retorts. Separated gas will be delivered to the surface through a 48 inch diameter bored hole and the oil and water will be pumped to the surface through another smaller bored hole. See Figure 2-6-2.

d. Retort 5 - This retort is 100 feet wide by 150 feet long by 400 feet high. The roof is arched for stability and the bottom is 'V'-shaped for collecting retort products. Access for development is at the top (B level), middle (C, E, and F levels) and bottom (G level). Pillars 245 feet and 310 feet wide separate Retort 5 from Retorts 7 and 4, respectively. See Figures 2-6-1 and 2-6-6.

e. Separator Room - Retort 5 - A separator room, 40 feet wide by 100 feet long by 40 feet high will be developed to receive and separate Retort 5 products. This room is positioned north of Retort 5 and at its bottom elevation so that products will flow by gravity to the separator. The separator is connected to a 48-inch diameter surface bored hole which will be used to transfer product gas to the surface.



REQUIRED POROSITY = 30% = 31,320 FT.^{3}
ACTUAL POROSITY = 31,524 FT.^{3} = 30.2 %
ROOFS BOLTED TO MAINTAIN STABILITY DURING DRILLING AND LOADING
ALL HOLES DRILLED UP-SIDES AND ARCH ARE SMOOTH WALLED.

Figure 2-6-4
MODULAR DEVELOPMENT PHASE - RETORTS 1 and 2

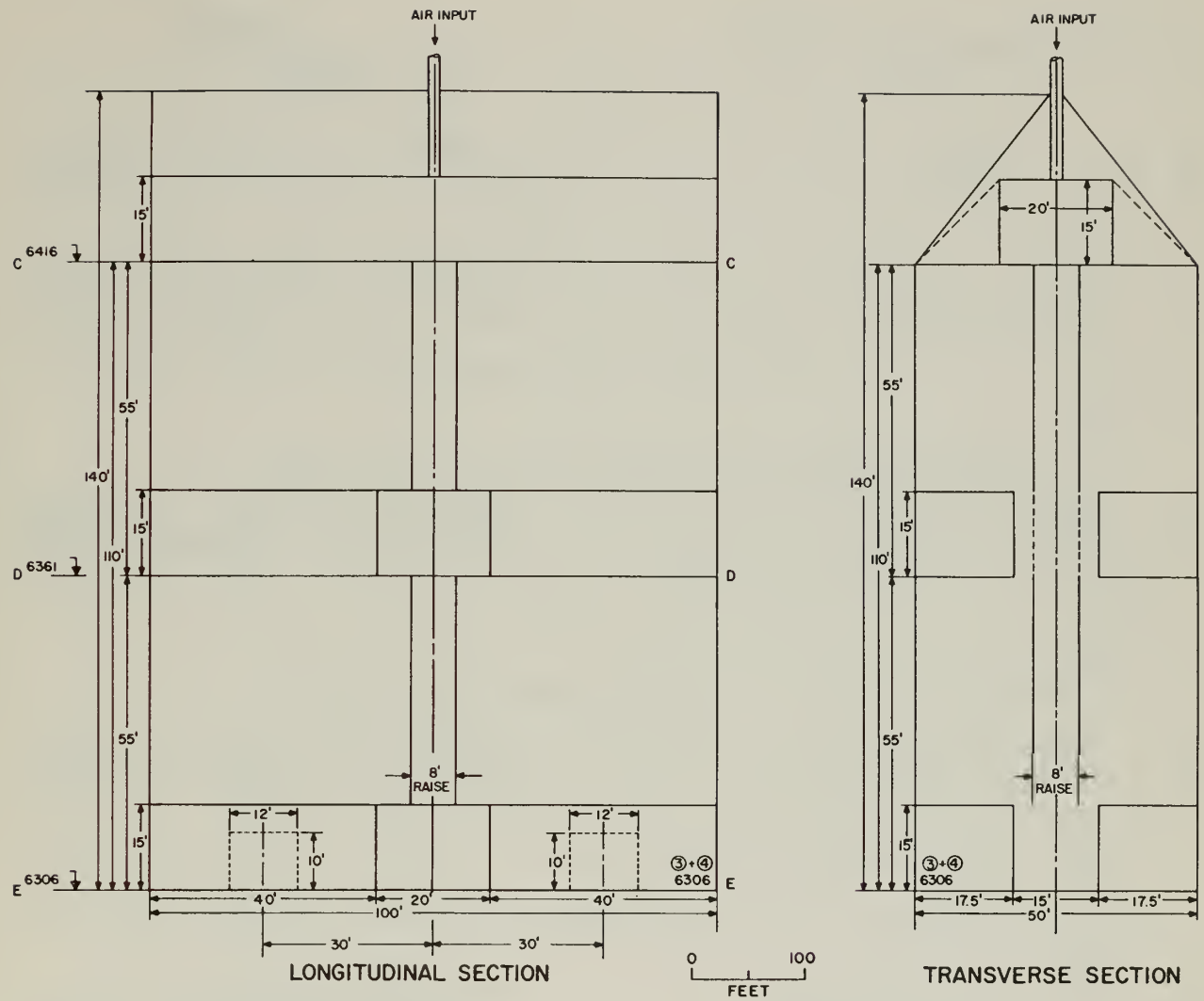


Figure 2-6-5

MODULAR DEVELOPMENT PHASE - RETORT 3 and 4

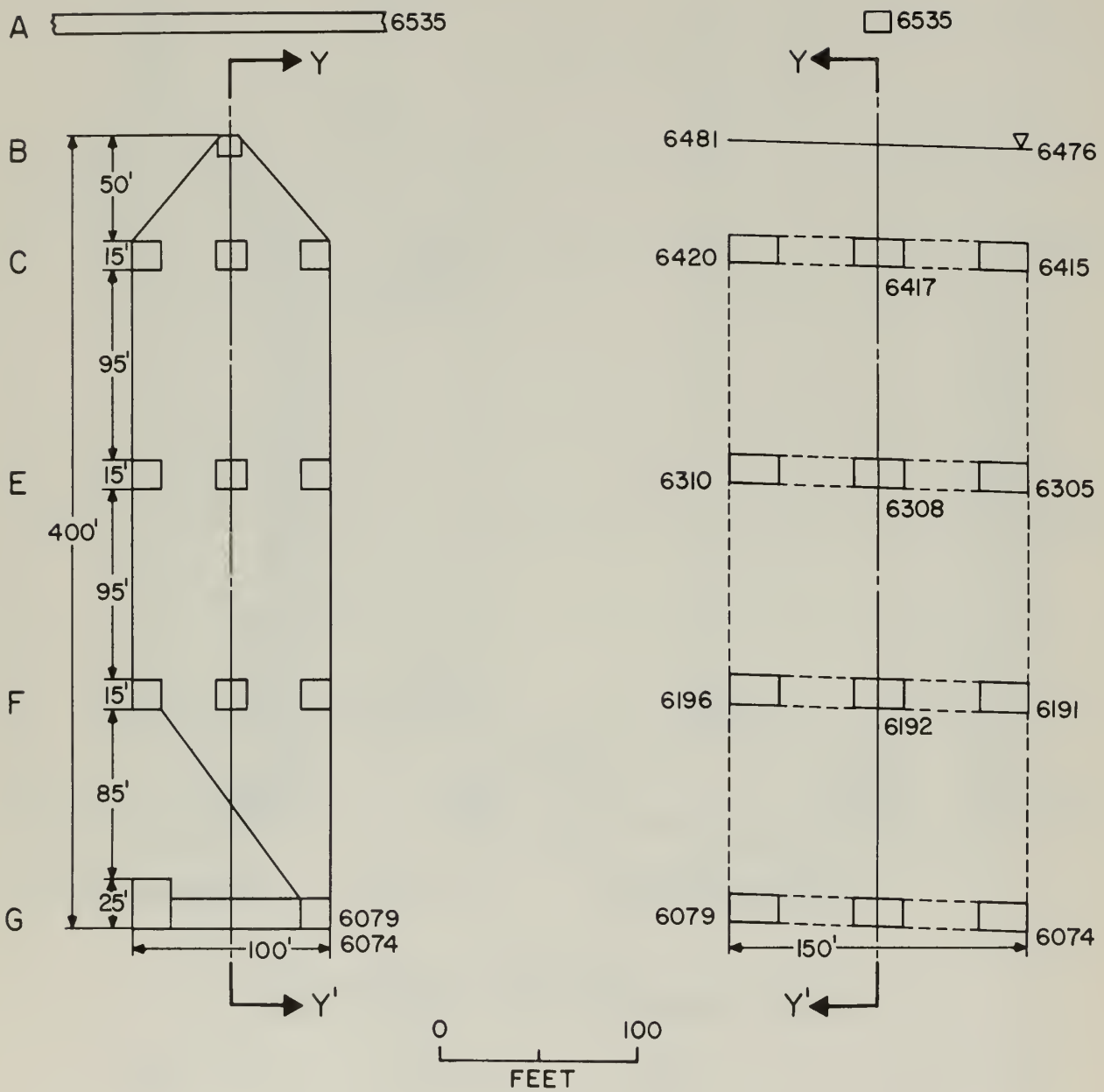


Figure 2-6-6

MODULAR DEVELOPMENT PHASE - RETORT 5

Product oil water will be pumped to the surface through another bored hole. See Figure 2-6-7.

f. Retorts 6 and up - These retorts are 150 feet wide by 300 feet long and are slightly less than 700 feet high. In order to achieve gravity flow through the sublevels to the shaft, the retort height was designed at something less than the 750-foot commercial retort height. Access for development is from B, C, E, F, G, H, I and J levels. Also, these retorts have arched roofs and 'V' bottoms. Pillars between retorts are 95 feet wide. See Figure 2-6-8. For relationship of all MDP retorts to stratigraphy see Figure 2-3-2.

g. Combustion Air Shaft and Level Distribution-Retorts 5-6 and up - A single 8-foot diameter bored-shaft from surface and connected to a single-level network of tunnels (B level) will be used to distribute combustion air to the Retorts 5-6 and up. See Figure 2-6-7.

h. Separator Room Retorts 6 and up - The separator room for Retorts 6 and up is the same size as the one for Retort 5. It is positioned west of Retort 7 and slightly below the bottom elevation of Retort 6. A 48-inch diameter bored hole for exhaust gas connects to the exhaust bored hole for Retort 5. Product oil and water are pumped to the surface through a separate and smaller bored hole. See Figure 2-6-7.

2. Development Method

a. Retorts 1-4 - Retorts 1-4 will be developed from C, D and E levels which are spaced at about 50-foot intervals. On each level, a major portion of the retort volume will be excavated to provide access for blast hole drilling rigs. See Figures 2-6-4 and 2-6-5.

The small access openings provide natural support and rock bolting requirements will be minimal. Blasted rock will be removed from the retorts using the same equipment and system used to develop the access drifts.

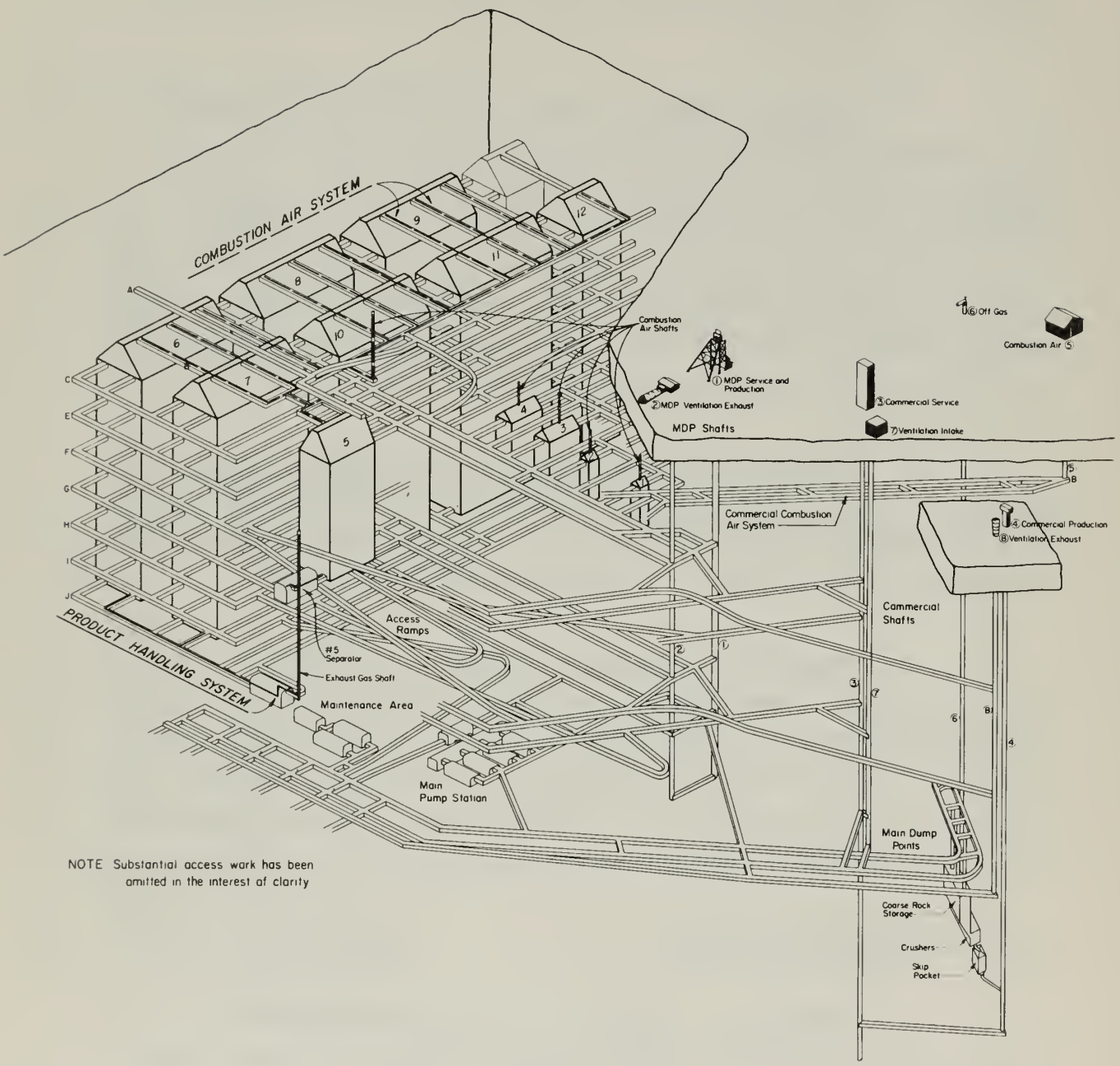


Figure 2-6-7

MODULAR DEVELOPMENT PHASE and COMMERCIAL ACCESS LAYOUT

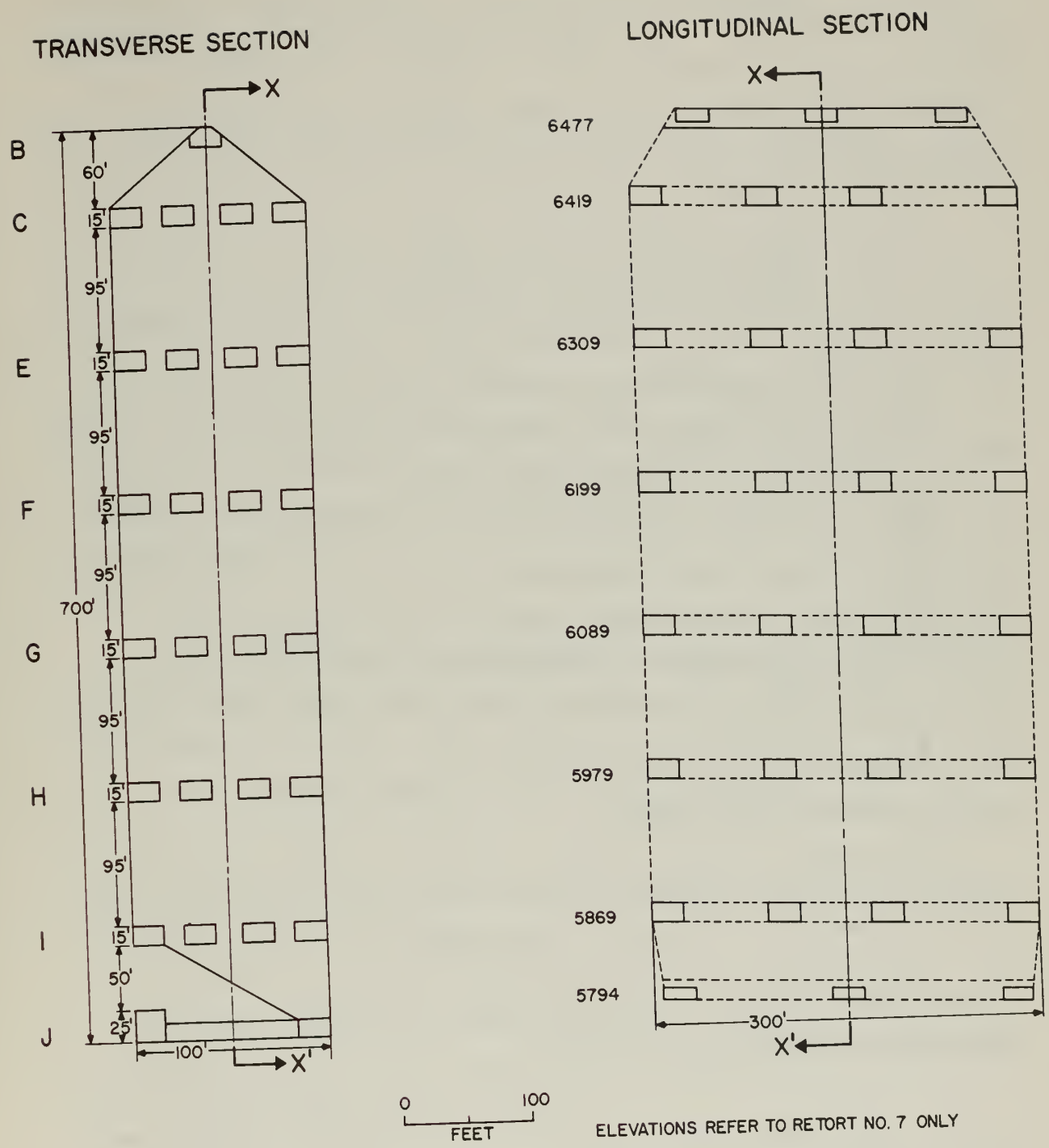


Figure 2-6-8
MODULAR DEVELOPMENT PHASE - RETORTS 6 and UP

b. Retort 5 - Retort 5 will be developed from B, C, E, F & G levels. The spacing of these levels is shown on Figure 2-6-6. Development will include driving one drift the length of the retort on B level; 3 parallel drifts on C, E, and F levels; and 2 parallel drifts on G level. Each drift on C, E, F and G level will be enlarged and interconnected with crosscuts.

c. Retort 6 and up - Each of these retorts have an air injection attic (B level), six mining levels (C, E, F, G, H and I) and one main haulage level (J). See Figure 2-6-8. Two drifts, 25 feet wide by 15 feet high, on each mining level will be driven first through the full length of the retorts. One J level drift will be enlarged to 25 feet high. Subsequently, within each retort, third and fourth drifts of the same size will be driven inside and parallel to the two outside sublevel drifts and they will be interconnected with four crosscuts per retort. Blasthole drilling will be accomplished with multiboom electro-hydraulic units similar to, but larger than, those used for regular drifting. Blasted rock will be loaded at the headings and hauled to bored rock-passes by LHD units. The bored rock-passes, one located in each retort will deliver the broken rock to loading chutes on the main haulage level. Diesel trucks will be loaded at the chutes and will haul the rock to a central rock-pass at the shaft.

Smoothwall blasting to minimize overbreak and damage to drift walls will be utilized where it is determined to be beneficial. This is particularly important where a drift passes through a pillar or parallels a permanent retort pillar. The effectiveness of this method will be thoroughly evaluated during the MDP.

3. Rubblizing - Rubblizing refers to the method of breaking rock within a retort and withdrawing a certain portion so that a desired void volume is achieved.

a. Retorts 1-4 - The first four retorts are significantly smaller than those proposed for commercial operation and therefore will be rubblized by a somewhat different system. The system, however, will

provide data to develop some of the significant features of the eventual commercial method. See Figures 2-6-4 and 2-6-5.

The upper, intermediate, and lower level drifts and crosscuts will be first excavated to provide drilling locations. One or more bored raises will then be drilled for the full retort height to provide a free face for fragmentation. The oil shale will be blasted in sections using vertical or near-vertical holes and ANFO explosives. Broken shale will be withdrawn by LHD units to attain the desired void volume.

During the rubblizing of these retorts, a comprehensive set of tests will be conducted to confirm or modify the selected blasting design. All phases of the drilling and blasting program will be evaluated with particular attention being given to the effect of blasting on retort walls (pillars).

b. Retort 5 - The increased size of Retort 5 allows rubblizing to be achieved by the method selected for the commercial retorts. This retort will be used to develop and perfect the method.

c. Retorts 6 and up - Rubblizing of these retorts will follow the same procedure required for rubblizing commercial retorts as described in the Commercial Phase. These are the first retorts from which dawsonite-bearing oil shale could be segregated for later alumina extraction, should this be desirable.

C. Broken Rock Handling - Broken rock handling refers to all those activities required to move blasted rock from development and production faces to surface dumps and/or stockpiles.

1. Mine Handling - Mine handling refers to those activities required to move mined rock from the development and production faces to the skip loading station.

a. Load-Haul-Dump Units (LHD's) - Five-cy LHD's will be utilized to load blasted rock at development and production faces. They will haul it to the rock-pass at the shaft or to rock-passes located near the working faces. During the early development stages, when working faces are within 500 feet of the shaft, LHD's will haul the rock to the shaft rock-pass. When the haul distance extends beyond 500 feet, LHD's will utilize more conveniently located rock-passes.

b. Shaft Rock-Pass - The shaft rock-pass is 8 feet in diameter and extends through all levels to the skip loading station. Below the main haulage level (J), the rock-pass intersects the lower aquifer. In this area, the rock-pass will be grouted and lined with concrete. Above the skip loading station, the rock-pass has a 500-ton live load capacity.

c. Internal Rock-Passes - As development moves away from the shaft, additional 8-foot diameter rock-passes will be bored through the sublevels to the main haulage level. Each of Retorts 6 and up will contain one rock-pass. Each rock-pass will be equipped with loading chutes on the haulage level.

d. Haulage Trucks - Diesel trucks (25-ton capacity) will be used to haul the mined rock from the chutes on the main haulage level to the shaft rock-pass. During the first three years, two trucks will be used. During the development and rubblizing of Retorts 6 and up, eight trucks will be used.

2. Hoisting - The service-production shaft will be served by a ground-mounted double drum hoist that has two cage-skip combinations operating in balance. Each skip (bottom-dump) has an 11-ton capacity and a hoisting rate of 24 fps (1400 fpm). The facility is capable of hoisting a maximum daily rate of 6,000 tons.

The bottom-dump skips will be loaded 1,130 feet below the surface at the skip loading station. Loading will be accomplished automatically to minimize cycle times. The skips will be hoisted to the surface and

their loads dumped into a 100-ton capacity storage bin that is attached to the headframe. Should tonnage quantities of dawsonite-bearing oil shale be needed for test work, the shaft and rock-pass might be assigned to this service as required.

3. Surface Haulage - Mined rock, run-of-mine size, delivered to the headframe bin will be transferred to 35-ton rear-dump diesel haulage trucks. These trucks will haul the rock to disposal piles located along the north slope of Airplane Ridge. See Section 4, Chapter 3, Development Ore Disposal Operation. If the option to segregate a small tonnage of dawsonite-bearing oil shale were elected, truck-haulage provides an easy means for delivering it where required.

D. Support Operations - Support operations refer to all activities related to the mine operation that were not previously covered.

1. Ventilation - During the development and burning of Retorts 1-5, ventilation intake air to the mine will enter through the service-production shaft and exhaust air will exit to the atmosphere through the ventilation shaft. The ventilation shaft will be equipped at the surface with a main fan installation. This fan will handle 200,000 cfm of air at 12 inches SWG (Static Water Gage), which is more than adequate for this segment of the MDP operation. See Figure 2-6-9a.

On each of the levels connected directly to the shaft, twin drifts will be carried to all major areas of operation. The main access drift will be used for air intake and the parallel return drift will be used exclusively to remove exhaust air and mine water drainage. Connections between these two drifts will be kept at a minimum and will be securely sealed with concrete when drifting is complete.

Fresh air for levels not directly connected to the shaft will be supplied through the access ramps. Connections will be made from the ramp exit

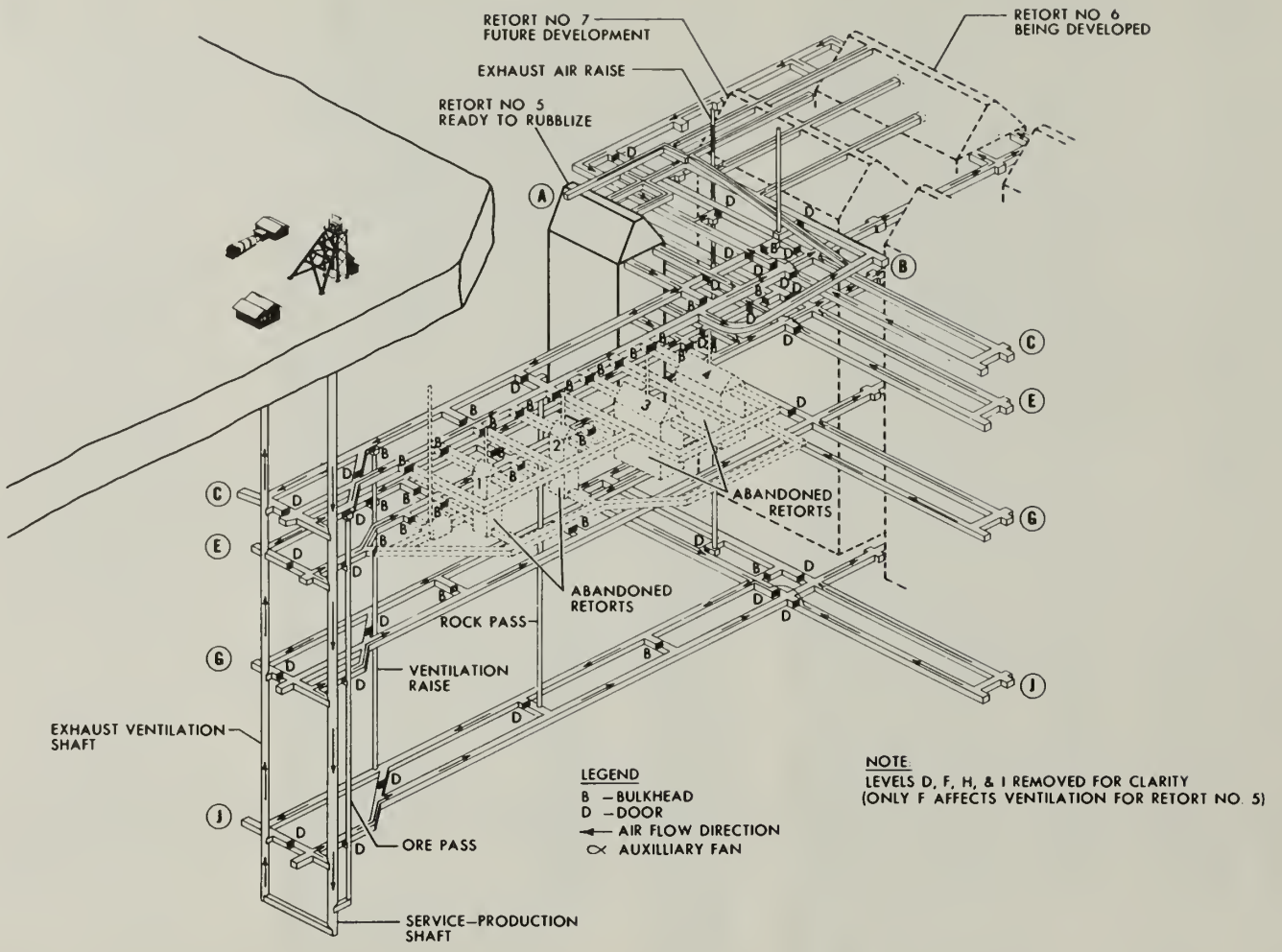


Figure 2-6-9a

MODULAR DEVELOPMENT PHASE

VENTILATION ARRANGEMENT AT START OF RUBBLIZING RETORT NO. 5

on each intermediate level to a pre-bored ventilation raise connected to the main exhaust system.

All development, except for ramps, is designed to advance as twin headings. This procedure establishes safe ventilation conditions with minimum use of auxiliary fans and ducting. A secure and efficient system is thereby assured. Where long ramps are required, connections will be made at appropriate intervals to ventilation raises.

No problems are anticipated in maintaining good ventilation in all working areas. In addition, the design provides secure fresh air access to all important areas of the operation during retorting with exhaust air from drifts in the vicinity of the retorts completely segregated.

During the later stage of the MDP when Retorts 6 and up are being developed, the MDP ventilation system will be adapted to provide air to the commercial mine headings being developed from the MDP mine. This system will include intake air being fed to the MDP headings through both parallel access and return drifts on each level and exhausting through bored holes to the surface, and intake air being fed to the commercial headings from the MDP service-production shaft and exhausting through the MDP exhaust ventilation shaft. One of the bored exhaust holes for the MDP operation between Retorts 5 and 6 will be equipped with a surface exhaust fan. Figure 2-6-9b shows the final stages of the MDP ventilation system when it is providing air for the initial stages of Commercial Development. Intermediate levels and ramps have been removed from figure for clarity.

2. Mine Drainage - The area to be covered by the underground operations will be initially dewatered by surface pump wells before mining begins. However, considerable residual water is expected in certain parts of the oil shale interval. Therefore, the levels have been designed to accept substantial water inflows.

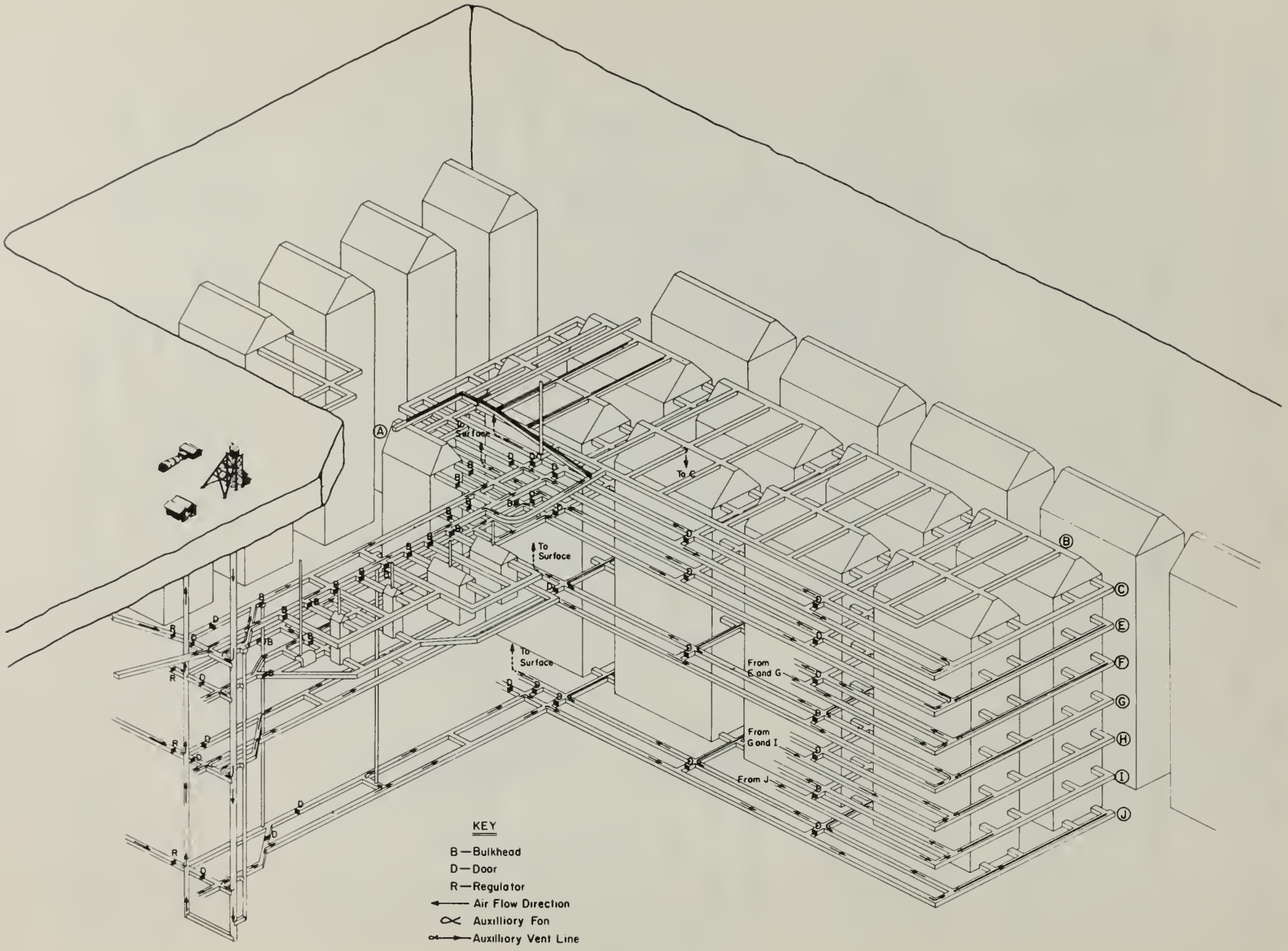


FIGURE 2-6-9b

MODULAR DEVELOPMENT PHASE - GENERAL VENTILATION LAYOUT

With minor exceptions, all drifts will be driven at positive grades to ensure gravity flow of water away from the working face. On each level, the mine ventilation return drift will be positioned at a slightly lower elevation than the main drift to provide an effective drain for mine water.

As soon as access is established, the main pump station on the main haulage level will be excavated and equipped. The station will have a sump capacity of 3.5 million gallons, adequate to ensure good settlement of solids and provide storage for inflow surges or pump outages. See Figure 2-6-7.

Water from higher levels will be delivered directly to the main haulage level sump through a bored hole. Most of the haulage level will be slightly below the sump and pump. Water from these lower areas will be pumped to the sumps by mobile submersible pumps. This arrangement ensures that the volume of the lower mine openings is available as emergency storage, thus providing added security to the shaft and pumping installations.

The main pump station will deliver water directly to the surface through pipelines in the service-production shaft. Prior to startup of the main pump station, water will be pumped to the surface through a series of relay stations located adjacent to the shaft stations.

3. Power - Initially, electrical power will be fed underground through the service-production shaft to substations on each level. Subsequently, a second cable route will be provided through a bored hole to a central transformer station and distribution center. Power will be distributed from this center to satellite substations in working areas.

Annual power requirements will range from a low of 800 KW in 1978 to a high of 6800 KW in 1983.

4. Maintenance - A service bay adjacent to the shaft area will be provided on each of the four levels that connect to the shafts. Each

facility will be capable of handling one unit (i.e. drill jumbo, LHD) at a time. Each will be supplied and equipped to perform all normal underground maintenance functions up to and including subassembly unit replacement.

Mobile maintenance equipment will not be used because of the relatively few pieces of major equipment required during the MDP and because of the limited mobility caused by late completion of ramp connections between some levels.

In 1985 and 1986, mobile maintenance equipment will be available to the MDP mine from the commercial mine maintenance facilities. This mobile equipment will have access to all MDP levels through the completed network of interlevel ramps.

5. Safety

a. Policy - The Modular Development Phase mine operation will comply with all applicable laws and regulations enforced by the Mining Enforcement and Safety Administration (MESA) and the State of Colorado. All employees will wear personal protective equipment and carry self-rescuers.

b. Health and Safety Program - Prior to the start of mining, a detailed Health and Safety Program will be developed under the direction of the Mine Safety Engineer. The Safety Engineer will also be responsible for the orientation and training of all employees in safety practices, including the use of personal protective equipment and self-rescuers; the supervision and training of first aid and mine rescue personnel; and the maintenance and control of first aid, mine rescue and fire fighting equipment. Additional information can be found in Section 6, Chapter 2.

c. General Practice

1) Fire Fighting - All mobile equipment will be equipped with fire extinguishers. Major fire-fighting control stations will be

established at critical locations such as shaft stations, workshops, powder magazines, etc. Water for fire fighting will be available at key locations and will be supplied from a surface reservoir that has the capacity to supply water at a rate of 1500 gpm for 6 hours. Also, fire water lines will be interconnected with the surface dewatering well and mine drainage systems so if a shortage develops, this source would be tapped. See Section 6, Chapter 3.

2) Explosives - Only minimal amounts of explosives will be stored underground. Such storage and handling will be effectively controlled by MESA, Colorado and the Treasury Department. All individuals required to use and handle explosives will be trained and under the direct control of an experienced supervisor. ANFO will be mixed on the surface prior to being taken underground.

3) Gas - A gas monitoring, warning and mine escape system will be developed for guarding against the potential threat of harmful gases entering working areas. The source for harmful gases could be a natural occurrence, diesel equipment or the retorting operation. Before any mining starts, this program will be approved by the appropriate authorities.

During the MDP, a thorough investigation will be made to determine the potential of retort product gas leaking into the mine working areas. If leakage should occur, corrective action will be taken. This may include sealing the leaking areas with gunnite or by grouting.

During the burning of Retorts 1-4, mining operations are scheduled on levels away from these burning retorts. The only personnel scheduled to be near the burning-retort area are those required for control and monitoring. An effective seal of the openings to the retort will be devised. A gas detection device will be used to monitor the seal and if leaks occur an alarm will be activated.

4) Noise - The operation will comply with all Federal and State noise regulations. A program of noise monitoring will be developed. Corrective action will be taken if standards are exceeded.

5) Airborne Particulates - A program for measuring the quantity of airborne particulates will be developed. If standards are exceeded, corrective action will be taken.

d. Fire Variance - The MDP operation will require the State of Colorado to issue a variance for lighting a fire underground before MIS retorting can commence.

e. Maintenance Shop Air - Exhaust air from the maintenance shops will be vented directly to the ventilation exhaust drift.

6. Communications - For the Modular Development Phase, telephones will provide the main means of communications. They will be available in each working area and at all permanent installations (shaft stations, maintenance bays, etc.). This system will connect directly to the surface, including the Mine Safety Department. To ensure continuity of communications, voice-powered units will be used and cable-runs to the surface will be duplicated. No major use of radio communication is planned for this phase due to the relatively limited extent of the mine.

7. Instrumentation - Access is planned around the retorts to allow installation of the instruments required for monitoring the retorting operation and measuring rock disturbances caused by both mining and retorting operations.

8. Service Hoisting - Each cage of a two cage-skip combination is capable of transporting 32 men each trip. The two cages have the capacity to deliver all materials and equipment required underground.

6.3 COMMERCIAL PHASE

The Commercial Phase for the Tract C-a Modified In Situ retorting operation has been scheduled for 30 years operation. During this time, an equivalent of four retorts will be burning at any one time.

The 30-year retorting operation is distributed over four individual retort fields illustrated by Figure 2-6-1. The design presented by the following is based on current knowledge. It is assumed that MDP experience will result in some changes to this commercial design.

A. Access - General mine access for the Commercial Phase includes a service shaft, production shaft, intake air ventilation shaft, exhaust ventilation shaft, combustion air shaft, retort offgas shaft and eight mining levels. Four of the mining levels are connected to the service shaft and the remainder are interconnected by ramps. See Figures 2-6-3 and 2-6-10.

1. Geometry - Commercial Phase mine workings, with the exception of shafts, are confined to the stratigraphic interval lying between the top of the R-8 zone and the bottom of the R-4 zone. See Figure 2-3-2. Shaft locations and the layout of retorts are illustrated by Figure 2-6-1 and 2-6-10. Characteristics of the various openings are as follows:

- The service shaft will be 34 feet in diameter, concrete lined, and connected to C, E, G and J levels. The design includes compartments for both large and small service cages, a ladderway, power cables and water lines.
- The production shaft will be 24 feet in diameter, concrete lined, and connected to J level (main haulage level).
- The air intake ventilation shaft will be 34 feet in diameter, concrete lined, and connected to C, E, G, and J levels.
- The exhaust ventilation shaft will be 34 feet in diameter, concrete lined, and connected to C, E, G and J levels.
- The combustion air shaft will be 16 feet in diameter, concrete lined, and connected to B level.

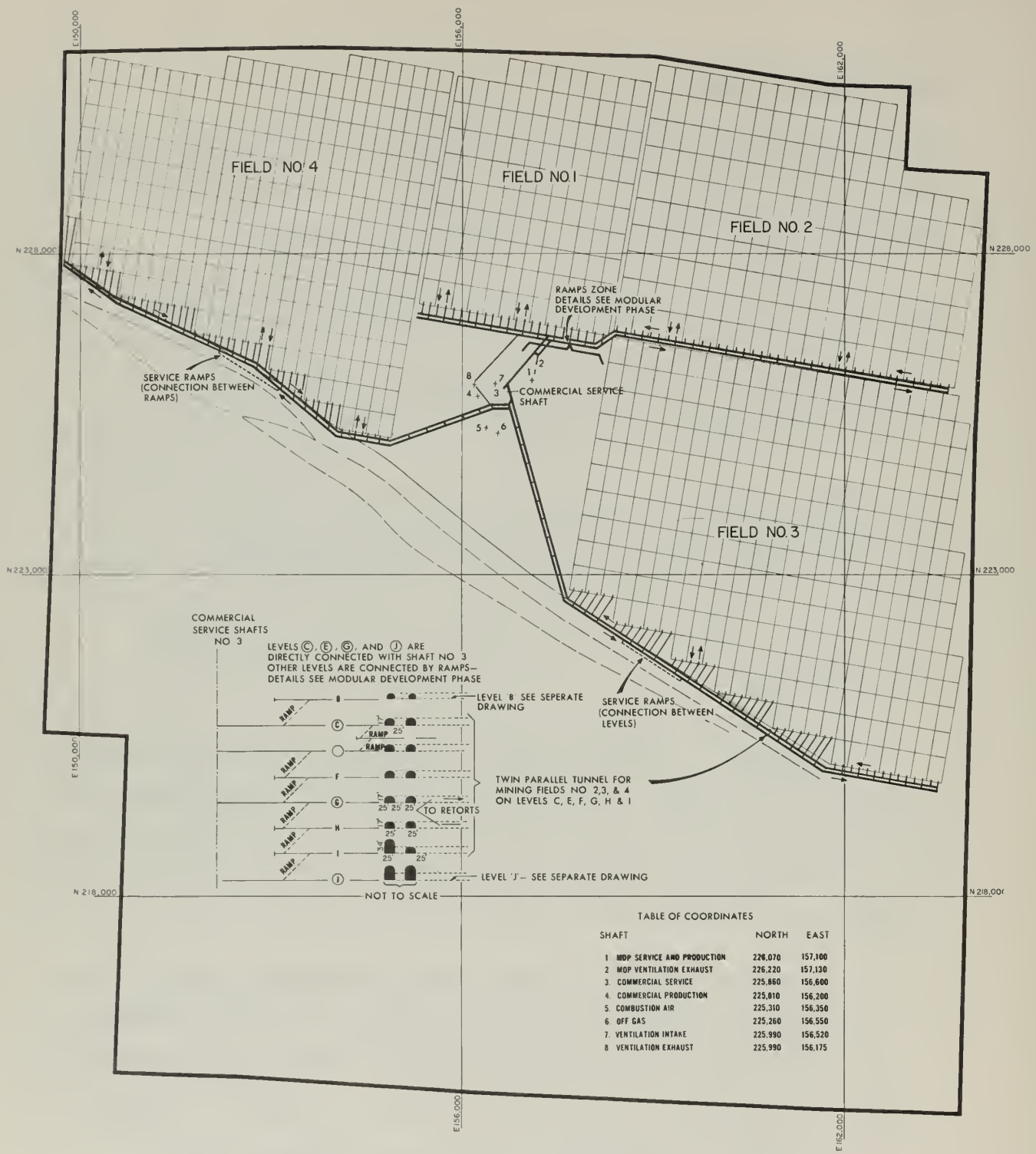


Figure 2-6-10

GENERAL CONCEPT OF TWIN PARALLEL TUNNELS,
LEVEL, E, F, G, H, I, J

- The retort offgas shaft will be 19 feet in diameter, concrete lined, and connected to the offgas tunnels.
- The air injection B level includes twin 16-foot by 12-foot drifts driven from the combustion air shaft to the retort fields. At the fields, one air injection drift is driven down the apex of each retort panel and these apex drifts (attics) are joined by three equal-spaced crosscuts per retort.
- Three sublevels (C, E & G) are driven from the service shaft to the intake air ventilation shaft and to the retort fields. The other three sublevels (F, H & I) are driven via ramps from other levels to the retort fields. All sublevel drifting cross-sections are 25 feet wide by 17 feet high. The drifts are single at the shafts but branch out to twins part way to the retort fields and continue through each retort panel as twin headings. Within each retort, two parallel equal-sized drifts are driven inside the twin headings and these four drifts are interconnected by four 25-foot wide by 17-foot crosscuts.
- The main haulage level (J) is connected to the service, air intake ventilation and production shafts. It is driven as twin 25-foot wide by 34-foot high headings to the retort fields. At the retort field, the twin-heading is driven the length of each retort panel. Within each retort, the twin heading is interconnected by three 25-foot wide by 17-foot high crosscuts.
- Four 8-foot diameter shafts will be bored to retort product separator pump rooms for ventilation and emergency escapeways. These shafts will range in depth from 1300 feet to 1500 feet. There will be one pump room and one shaft for each field.
- During the sinking of the service and production shafts, excavations will be completed for the crusher installation and other shaft stations.

2. Development Method

a. Shafts - All shafts, except the combustion air and pump-room ventilation shafts, will be sunk by conventional methods. The combustion air shaft will be upreamed and the pump room ventilation shafts will either be bored or upreamed depending on the development rate of the separator system.

b. Drifting (All Levels) - Drifting will be accomplished by well proven techniques. Full-face rounds will be drilled by multiboom jumbos mounted with electro-hydraulic rock drills. ANFO will be used for blasting. LHD units will remove and dump the blasted rock in 8-foot diameter bored rock-passes (except on main haulage level where LHD's will dump directly in haulage trucks). Bored rock-passes will be positioned to achieve maximum operating efficiency from the combined LHD-truck haulage operation. The top and bottom levels will be driven in advance of the intermediate levels to permit timely boring of the rock-passes. On the main haulage level, 50-ton diesel trucks will be loaded at the rock-passes through loading chutes. The trucks will haul and dump in three bored rock-passes at the crusher station.

Considering the large dimensions of some of the openings and their long life, systematic rock bolting is planned. Bolting will be accomplished using mobile automated units. Smoothwall blasting will be used where it improves wall rock characteristics and reduces the requirement for rock bolting.

The possibility of using mechanical miners for drifting will be evaluated during the detailed design stage. This technique is particularly attractive for air and gas tunnels where the resultant geometry increases stability and the smoother walls contribute to less maintenance, improved air and gas flows and lower power costs.

B. Retort System - The retort system includes 4 fields containing a total of 932 retorts. Field 1, containing 117 retorts, is north of the

shaft pillar; Field 2, containing 182 retorts, is northeast; Field 3, containing 308 retorts, is east; and Field 4, containing 325 retorts, is northwest.

1. Geometry - All 932 retorts within the four fields will be 150 feet wide by 300 feet long and average about 750 feet high. Height varies because design parameters place the top and bottom of the retorts in two diverging stratigraphic zones, the R-8 and R-4. This divergence is caused by basinward thickening of the retort interval across the tract to the northeast. See Figure 2-3-2.

a. Retorts - Placement of the apex of each retort at the top of the R-8 zone and the bottom at the base of the R-4 zone provides a stratigraphic interval of good-grade oil shale for retorting and at the same time avoids a major portion of the lower aquifer.

The roof of each retort is arched to ensure retort stability and to provide a plenum for proper distribution of combustion air. Three crosscuts connect the top of the retort arch to the attic drift in the adjacent retort for introduction of combustion air. The retort base is V-shaped with three crosscuts connecting the bottom of the 'V' to a longitudinal collector drift. Products will flow from the retort through the crosscuts to the collector (exhaust) drift. See Figure 2-6-11.

All retorts are arranged in parallel panels (rows) along their long axis. These panels span the retort fields and dip to the northeast in conformance with stratigraphy. In all cases, development of retort openings (drifts, crosscuts, etc.) will progress away from the shaft access drifts the total length of the panel while retort rubblizing and burning will progress through the panel in the opposite direction from the field boundary to where shaft access drifts enter. For Field No. 1, panels will be developed in sequence from east to west. See Figures 2-6-11 and 2-6-12.

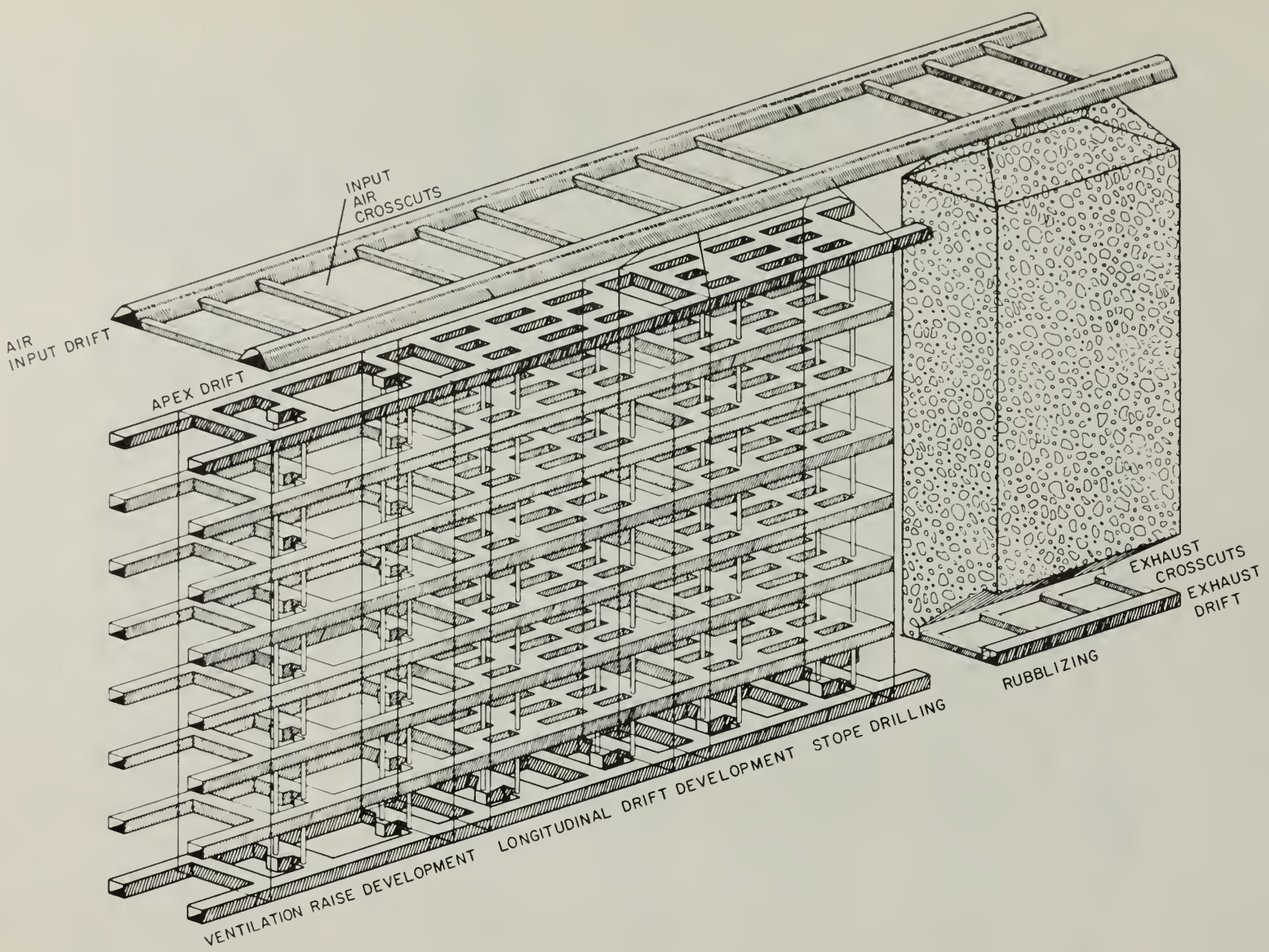


FIGURE 2-6-11

SCHEMATIC STOPING SEQUENCE

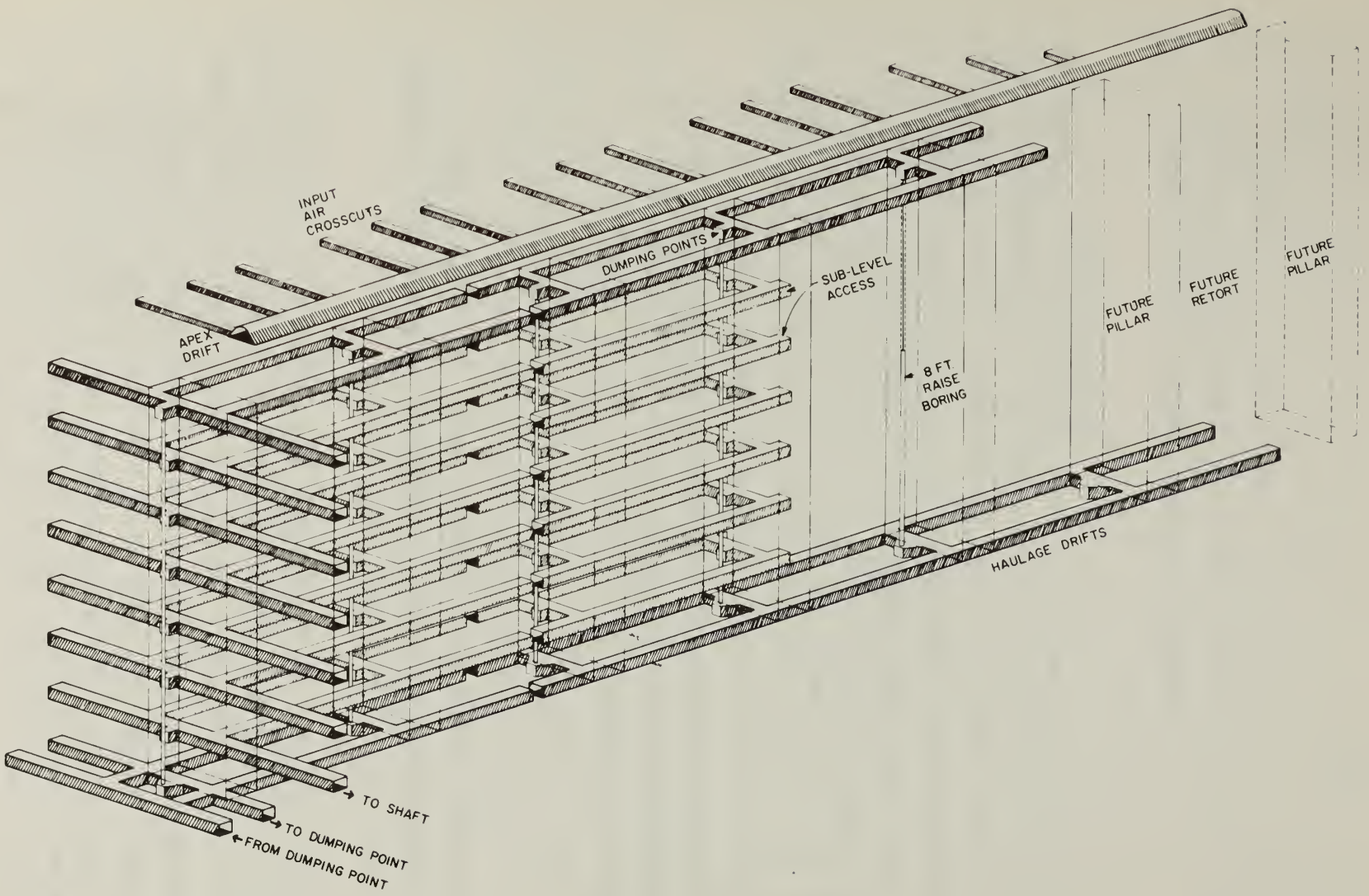


FIGURE 2-6-12

SCHEMATIC ACCESS DEVELOPMENT - GENERAL STEPS

b. Pillars - Retorts are separated by pillars of intact rock which serve to limit the lateral propagation of retort-combustion, to confine the retort gases to the rubblized room (retort), and to support the overburden. The thicknesses of these pillars vary with depth of overburden and are designed to remain stable throughout the retorting process. Pillar thickness within each of the four retort fields is constant but varies between the fields.

Available rock mechanics data were used to design these retort-separation pillars, as well as retort roofs and major underground openings such as product separator rooms. The first design step involved evaluation of previous rock mass and diamond drill core strength data published for the Anvil Points and Colony demonstration oil shale mines. The ratio of the rock mass with diamond drill core strengths was then determined. Thus, for Tract C-a, knowing the diamond drill core strength of the Mahogany zone, the mass strengths could then be estimated. The second step compared the mechanical and structural geological properties of the rock sequence of the Commercial Phase pillars with the properties of the Mahogany zone. In this manner the rock mass properties of the entire column of rock forming the pillars could be estimated.

Other factors examined prior to estimating the required pillar thickness included: support provided by the rubble before, during and after retorting; effect of blasting on retort walls; and effect of temperature (both short and long-term). These effects were analyzed from published data and tests carried out specifically for this design.

The determination of stresses which are expected to exist in the pillars was based on the tributary theory supported by theoretical stress analysis techniques. Thus, the stress levels at differing depths in the pillars were compared with strength values at a given depth and an adequate safety factor was applied to arrive at a pillar thickness for varying depths of overburden. This design assumes that fully depressurized groundwater conditions exist. These conditions will be achieved by dewatering.

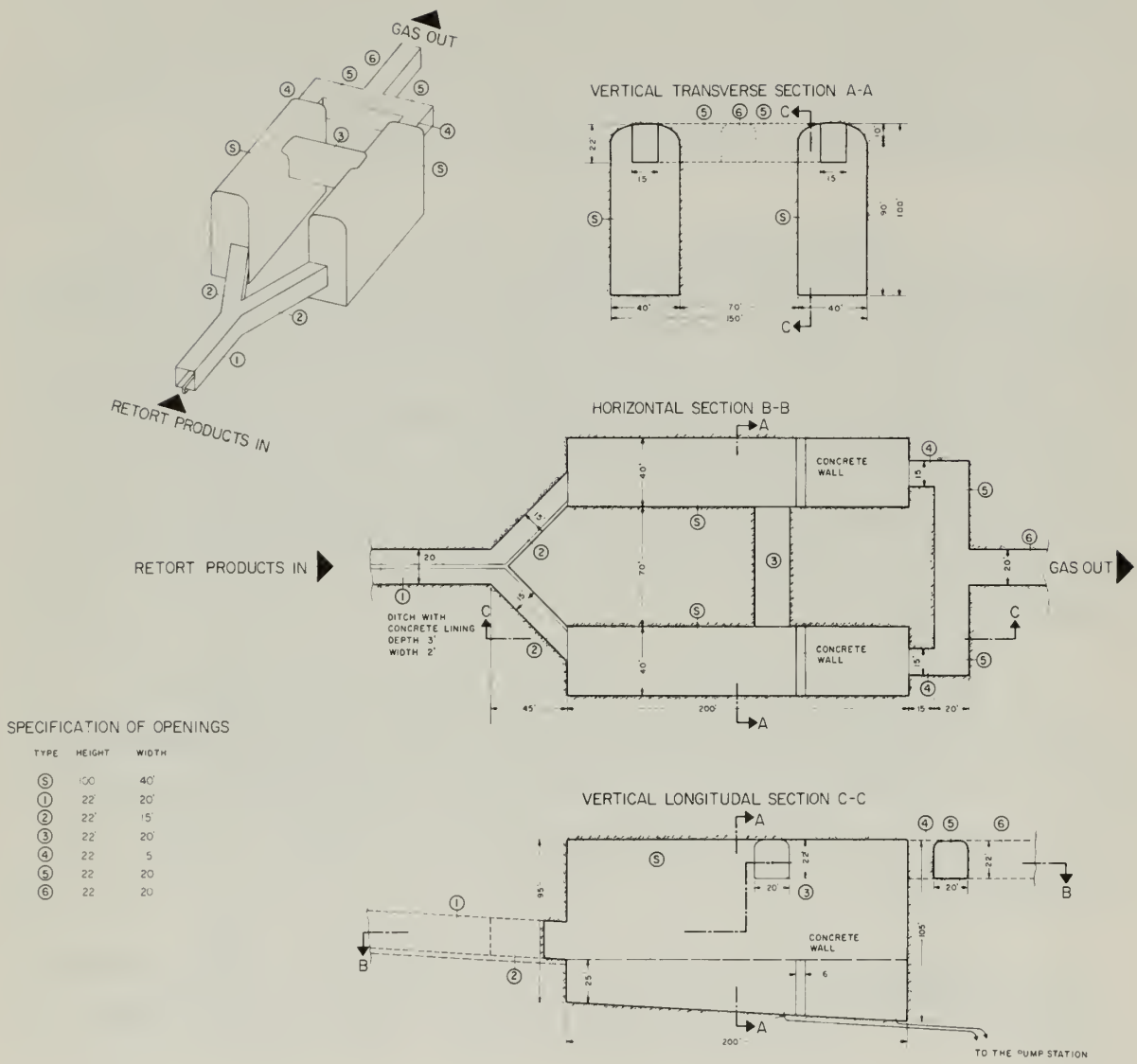
The long axis of the retorts is oriented N10°E. This orientation was selected as a compromise between roof stability requirements (orientation of rock-joint patterns) and minimizing the operational slope of mining drifts. The product collection tunnel (exhaust drift) at the base of each retort also dips to the northeast and allows for a gravity flow of retort products in that direction towards a separator.

c. Separator System - Retort products (oil, water and gas) will flow from the retorts through collection tunnels to a two-chambered separator. Each chamber is 40 feet wide by 200 feet long by 100 feet high. See Figure 2-6-13. From the chambers, retort gas flows through a tunnel to the retort offgas shaft through which it is delivered to the surface. Also from the chambers, oil and water products will gravity flow to a pump room where they will be pumped through a tunnel and MDP ventilation shaft arrangement to the surface. Each retort field has one separator system.

2. Development Method - The method of developing commercial retorts is the same as described previously for the Modular Development Phase commercial-sized retorts. However, it is recognized that experience gained from the MDP retorts may result in changes to these plans. See Figure 2-6-11.

3. Rubblizing - All Commercial Phase retorts will be rubblized by a technique that incorporates features of the sublevel caving mining method.

The initial step following retort development (driving of drifts and crosscuts on each level) is to prepare a slot at the end of the retort. This slot provides a free face for blasting. Next, blast holes are drilled up from the network of drifts and crosscuts. When a certain number of holes are completed on a level, they are loaded with ANFO and shot. The drilling and blasting operation starts at the far end of the retort panel (down-dip) and retreats toward the shaft access. Retreat on the top level leads and the lower levels follow en échelon. See Figures 2-6-11, 2-6-12, 2-6-14 and 2-6-15.



SPECIFICATION OF OPENINGS

TYPE	HEIGHT	WIDTH
⑤	100	40'
①	22'	20'
②	22'	15'
③	22'	20'
④	22	5
⑤	22	20
⑥	22	20

FIGURE 2-6-13
SEPARATOR

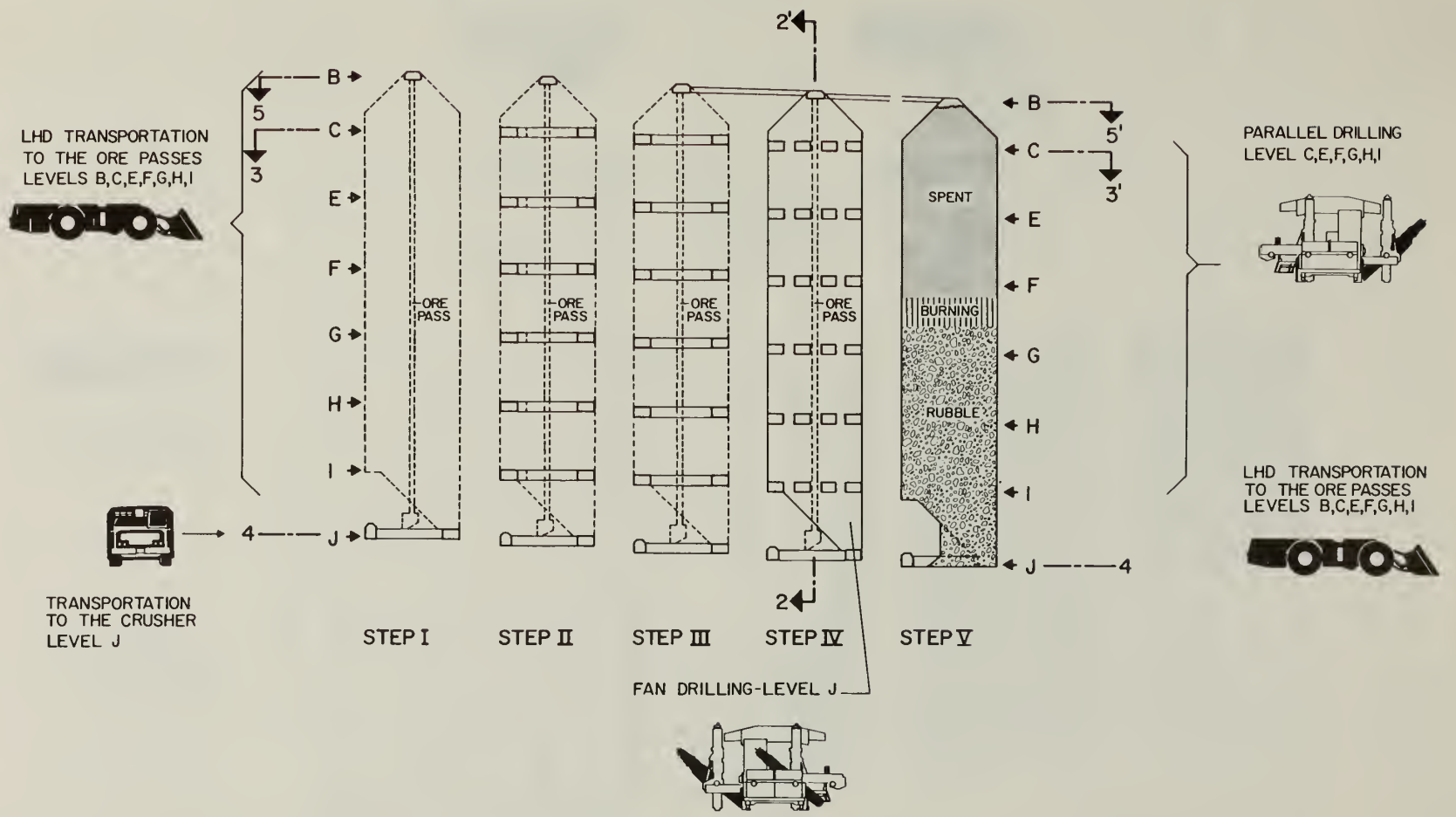


Figure 2-6-14

GEOMETRY OF RETORTS-EQUIPMENT

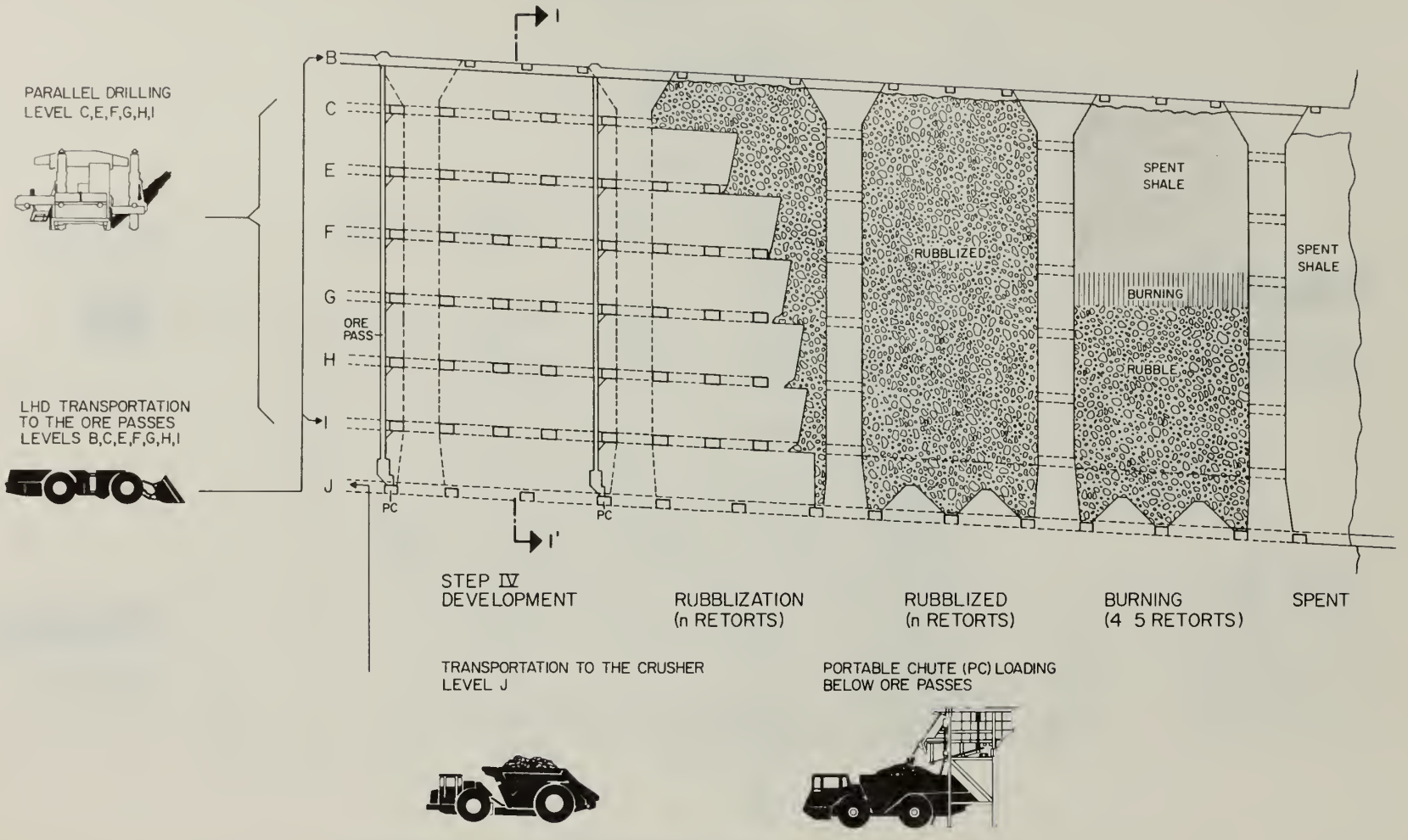


Figure 2-16-15

GEOMETRY OF RETORTS - EQUIPMENT

After each blast, a portion of the shale is withdrawn by LHD units operating on the sublevels. The amount withdrawn is determined by the required rubble void volume. See Figures 2-6-14 and 2-6-15.

The rubblizing process will include smoothwall blasting along the retort walls if this operation is proven successful during the Modular Development Phase. Smoothwall blasting, theoretically, protects the pillar from induced fracturing by minimizing the transfer of blasting energy to the walls. After a retort is completely rubblized, openings to the retort (other than air inlets and gas outlets) will be sealed by concrete bulkheads or other suitable means.

C. Broken Rock Handling - Broken rock handling refers to those activities required to move mined rock from development and production faces to a surface stockpile.

1. Mine Handling - Mine handling refers to those activities required to move broken rock from the development and production faces to the skip loading station.

a. Load-Haul-Dump Units (LHD's) - LHD activity for the Commercial Phase is similar to that previously described for the LHD's operation during the MDP. The only exception is that this operation will not require LHD's to haul rock to the production shaft. See Figures 2-6-14 and 2-6-15.

b. Retort Rock-Passes - One 8-foot diameter rock-pass is included with each retort. Each rock-pass is equipped with a loading chute on the main haulage level. See Figure 2-6-15.

c. Haulage Trucks - Fifty-ton diesel trucks will haul the mined rock from the loading chutes on the main haulage level to the crusher station where the rock will be dumped into three separate dump raises. See Figure 2-6-15.

The truck haulage level includes separate drifts for incoming and outgoing traffic. This arrangement provides for a safe and efficient operation of the truck fleet which at times will exceed 25 units.

Haulroad design in most areas is controlled by the natural dip of the deposit. However, when conditions warrant, roads will be developed to the most efficient grades. Anticipated average grades are:

- In Retort Rows — 3% against load
- Other — $\pm$6% depending on area served

Main haulage roads will be constructed with materials that will hold up under the heavy traffic of haulage trucks. Roads will be slightly crowned and ditched to allow proper drainage. They will be maintained by grading which will lower maintenance and tire costs.

2. Crushing - Two impact-crushers will crush rock fed by pan-feeders from the 10,000-ton capacity storage raises. Each impact crusher has a rated throughput of 1200 tph. Each crusher will discharge a minus 8-inch product into a common 8000-ton storage bin. See Figure 2-6-3. A smaller alternate feed and discharge storage system may be considered in the future for segregation of dawsonite bearing oil shale.

3. Hoisting - Rock hoisting will be accomplished with two identical 4000-hp four-rope Koepe friction hoists mounted in a concrete tower. Each hoist will be fitted with two 25-ton bottom-dump skips.

The hoisting operation will be fully automated for maximum efficiency. The hoisting cycle consists of skip loading at the loading station (1540 feet below surface), hoisting and dumping the rock into one of two 800-ton discharge bins attached to the headframe.

4. Surface Transport - Primary crushed ore will be transferred from the mine headframe rock bins to a belt conveyor system by a combination of vibrating feeders and short belt conveyors. The rock will be

transported overland by the conveyors to the primary ore stockpile. If the underground bins for segregation of dawsonite-bearing oil shale are installed, a tripper will be provided on the primary belt so that this material can be diverted from the normal stream.

Primary crushed ore will be produced during 1985 and 1986. However, surface retorts will not be operational until 1987. During these two years, the ore will be transferred from the primary stockpile to a temporary conveyor connected to the discharge conveyor of the processed shale conveyor system. These conveyors will transport the development ore to the processed shale truck loadout bin. This ore will be hauled from the bins by bottom-dump trucks and placed in a nearby ore disposal pile. See Section 4, Chapter 3, Development Ore Disposal Operation.

a. Design Criteria - Design will be in compliance with CEMA (Conveyor Equipment Manufacturers Association) standards.

b. Location - The overland transportation system will consist of three belt conveyors, originating at the production shaft tipple and terminating at the primary crushed ore stockpile. The overland belt conveyors follow the natural contour of the land where possible. Topography will be changed by cut and/or fill where necessary for conveyor or service road construction. A service road will be constructed adjacent to the conveyor system to permit its periodic inspection and service. The service road and the conveyor belt will require about a 25-ft. wide corridor.

All conveyors will be enclosed by semi-circular hoods to control dust and protect conveyor belting. The conveyor hoods will be designed to facilitate maintenance of conveyor components and inspection of the belts.

c. Equipment Selections - The alignments and profiles of these belt conveyor systems will be optimized to provide transport systems which are environmentally sound and economically justifiable.

Topography dictates that portions of this conveyor system be elevated on steel trusses to allow wildlife to pass beneath.

A walkway paralleling the conveyors will be lighted for night-time operations. Emergency stop switches which can be operated by plastic-coated pull cables from any point along either side of the conveyor will be spaced at 200-foot intervals. The conveyor frame will be electrically grounded through ground rods along the conveyor. A series of visual and audible alarms along the conveyor length will be automatically initiated for an adjustable time period prior to actual startup of the conveyor belt. Side-travel, plugged-chute, torn-belt, under-speed and fire detection shutoffs will protect the conveyor system.

An enclosed transfer station will be provided where the transport system changes direction and material is transferred from one belt conveyor to the next. Dry-type dust collectors will be installed to capture dust generated at these points.

5. Primary Crushed Ore Storage - Under normal operating conditions, this large conical pile contains 100,000 tons of minus 8-inch crushed oil shale. Approximately 30% of the pile is "live" or moveable by gravity without assistance from auxiliary mobile equipment.

The end of the last conveyor of the overland transport system is elevated to discharge into a 12-foot diameter, concrete lowering tube about 120 feet high. Rectangular wall openings allow material to flow outward to form the storage pile. The openings are located at varying elevations in the tube wall to reduce dust generation and material degradation. The lowering tube also provides support for the discharge end of the last conveyor in the overland system. The top of the lowering tube will be enclosed and provided with a baghouse to control particulate emissions. Plans include a provision for stockpiling Dawsonite adjacent to the main stockpile.

D. Support Operations - Support operations refer to all activities related to the mine operation that have not been covered by the preceding.

1. Ventilation - During normal Commercial Phase operations, 4,000,000 cfm of ventilation air will be drawn through mine workings by a battery of six horizontal two-stage axial flow fans mounted at the collar of the exhaust ventilation shaft. These fans will be operating at 20 inches SWG (Static Water Gage). Underground use of a large number of 50-ton diesel haulage trucks is the main reason for the high volume air requirements.

Fresh air will be distributed to the retort panels through the main access tunnels on each level. Distribution to the levels not directly connected to the shaft will be through both the ramp system and bored raises.

The system of return drifts underground will parallel the intakes described above. Connections between the two systems will be kept at a minimum during the development stage and will be isolated from each other in operation except in the retort panels. Isolation will be accomplished by sealing all crosscut openings with concrete bulkheads.

Development of the retort panels will initially be carried out in twin headings. All subsequent stages of retort preparation have also been designed and scheduled to provide good airflow in working places with a minimum of reliance on auxiliary fans and ducting.

2. Mine Drainage - The first two commercial retort fields lie to the north and northeast, down-dip from the Commercial Phase service shaft. Development of the initial retort panels will therefore be downgrade and mine inflow water will have to be removed from the working faces by pumping. As soon as development reaches the limit of the field, a satellite pump station will be excavated and placed in operation at that location. This facility will consist of a de-gritting sump and submersible pumps which will deliver the water to the main station sumps near the service shaft.

The system will have the advantage of a large emergency storage capacity below the main station and will obviate the need to provide different main stations for each stage of mine expansion.

3. Power - Electrical power will be delivered underground at 13.8 KV through two separate cable systems. On the main haulage level, this voltage will be fed to a control switching and transformer station. From this station, the 13.8 KV will be fed to a main substation on each sublevel. At the substations, the voltage will be reduced to 4160 V and delivered to mobile substations positioned near the main operating area. At these locations, a final voltage reduction to 440 V (operating voltage) will be made.

This arrangement will minimize power losses and voltage drops due to excessive transmission lengths at low voltage. Cable runs and switch gear will be arranged to provide maximum security of feed to all distribution points. Particular care will be taken to protect the power supply to pumping and ventilation equipment.

4. Maintenance - The main workshop complex will be located on the main haulage level where the heaviest density of mobile equipment occurs. See Figure 2-6-7. This facility will be used to maintain and repair the large fleet of haulage trucks and other equipment that operates on this main level. Equipment on other levels requiring major repairs, such as planned overhauls, will be delivered to this complex for the necessary work.

Each level will have a service bay that is equipped to do fueling, welding and equipment washing. Each facility will also have cranes to assist in performing subassembly replacements. Special equipped vehicles also will be available in the working areas to provide lube service and minor repair work.

No rebuilding of components will be performed underground. Any units requiring rebuilding (engines, transmissions, axle assemblies, etc.)

will be replaced in total and sent to surface for rebuilding at site workshops or by outside contractors.

5. Safety - The commercial mine will be operated under the same Health and Safety guidelines introduced for the Modular Development Phase. Any improvements in safety practice developed in the MDP will be incorporated in the Commercial Phase.

Throughout the life of the Commercial Phase, the MDP service shaft will remain on standby for emergency transfer of personnel.

All four pump room-to-surface ventilation shafts (part of product separator system) will be equipped as emergency escapeways for personnel. Equipment will include small, single-drum, surface hoist and capsule.

6. Communications - A complete coverage telephone system similar to that described for the Modular Development Phase will be implemented in the Commercial Phase. Due to its wide coverage, the system will be automatic-direct-dialing. This system will have additional backup voice-powered units positioned at strategic locations such as escapeways. The automatic system will be equipped with emergency battery units to ensure continued telephone communications during any power outage. See Section 5, Chapter 6.

Maximum use will be made of radio communications to optimize the efficiency of operations and maintenance. Truck haulage performance can be aided considerably through radio communications.

7. Service Hoists - Main access to the underground mine for personnel, equipment and supplies is through the service shaft. Two hoists will operate in this shaft. The larger one, a ground-mounted friction type hoist, connected to a 14-foot wide by 32-foot long single deck cage (37-ton capacity) will be used to transfer heavy equipment and supplies between the surface and the various mine levels. Equipment transfer will be done rapidly with only minor disassembly. The smaller chippy

hoist, a double drum unit with single side clutching connected to a smaller service cage, will be used to move personnel and materials between the mine levels and the surface.

CHAPTER 7
SCHEDULES

7.1 DEVELOPMENT AND CONSTRUCTION

A. Modular Development Phase (MDP) - Figure 2-7-1 shows the mining schedule through the Modular Development Phase and up to the first commercial burn. Mobilization for shaft-sinking operations will begin in September 1977. A program of detailed core drilling will be undertaken simultaneously, the purpose of which is to obtain site-specific geologic and hydrologic data at the shaft sites. The shafts are expected to be operational early in 1979. Initial underground development work will concentrate on access to the first retorts. Rubblizing of Retort 1 will begin in September 1979 for burning at the end of the year.

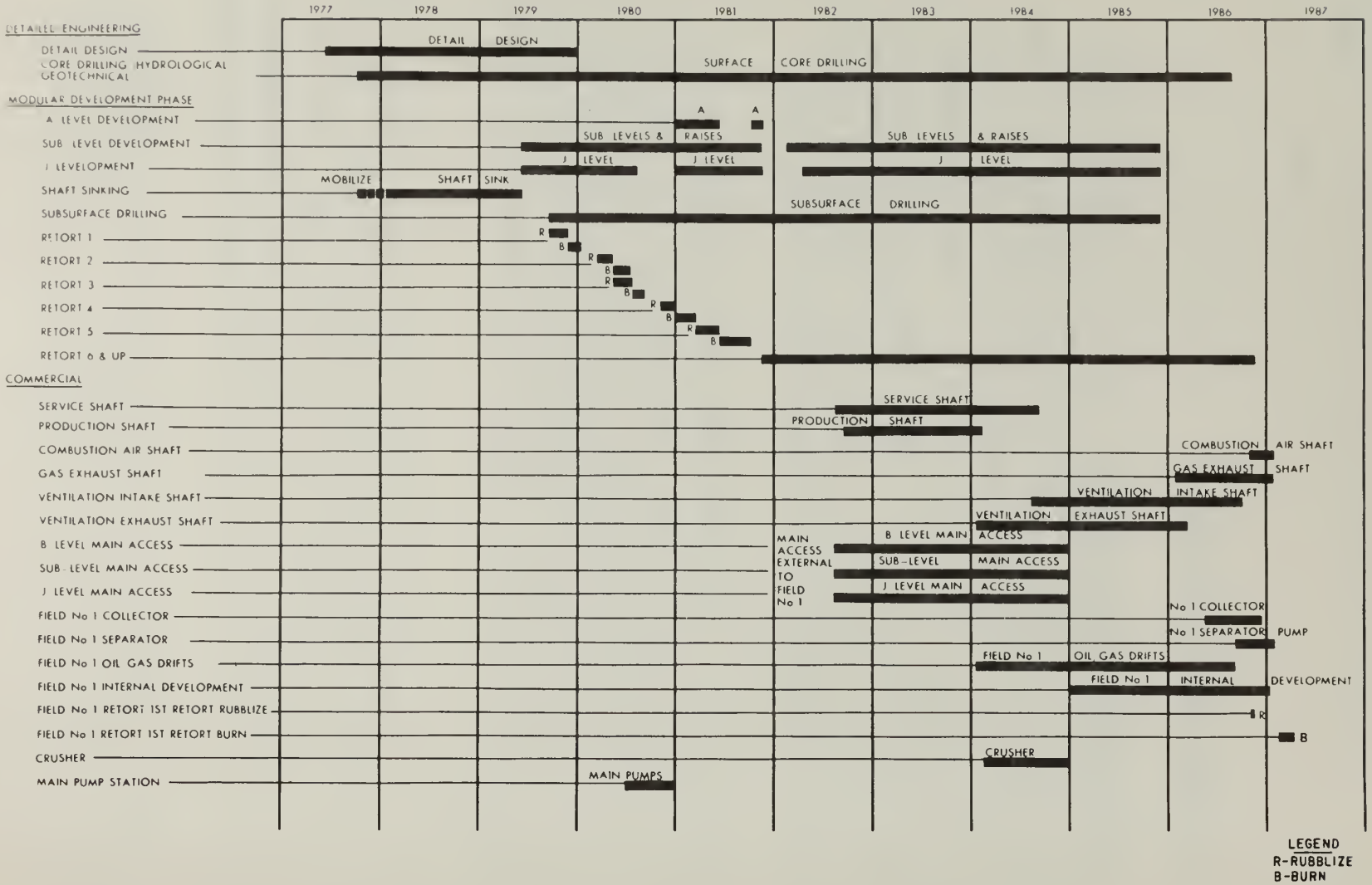
Development of Retort 2 will begin shortly after the results of the Retort 1 burn have been evaluated. This sequence will be repeated for all of the subcommercial size retorts (1 through 5). The haulage level will be advanced steadily throughout most of this period. Initially it will serve as access to the main pump station and then will be extended to provide timely access to the locations of the rock-passes serving the upper levels.

Retort 5 will be operational in mid-1981 and is expected to produce the data required for completion of the full-scale retort design. The first commercial-sized retort (Retort 6) will be burned in 1982. There will be continuous production of oil from the start of the second commercial-sized retort in 1983 until the commercial construction has been completed.

B. Commercial Operation - The information developed from the Modular Development Phase is expected to be adequate by 1982 to permit adoption of the final design for the main commercial mine. In order to minimize

Figure 2-7-1

SUMMARY MODULAR DEVELOPMENT PHASE MINING SCHEDULE



the development time for this operation, underground development work will commence from the MDP shafts simultaneously with the sinking of the commercial shafts. Adequate capacity has been designed into the MDP shaft system to permit commercial main access to Field 1 to be essentially completed by the end of 1984. At that time, the main service and production shafts are scheduled to be operational.

Development of the initial panels of commercial retorts will be accomplished in 1985 and 1986, permitting commercial production to begin in February 1987. During this development period, the ventilation and retort air and gas shafts, underground separators and other ancillary facilities will be completed.

7.2 COMMERCIAL MINE PRODUCTION SCHEDULING

In order to assure a steady production of oil and gas from the mine at the required rate throughout the life of the mine, the 932 retorting modules were subjected to a Critical Path Analysis.

Constraints were imposed upon the analysis regarding the number of retorts burning, the ignition pattern, safety of operation and mine stability. In addition, the analysis was constrained to reduce capital expenditure to a minimum and also to delay such expenditure to the latest feasible time.

In order to promote safety, retorts will be burned in a retreating sequence, updip, with men and ancillary operations being located in essentially undisturbed ground. In addition, the assumption was made that at least one rubblized retort would be pressurized with fresh air adjacent to a burning zone. Further, the sequencing analysis minimized the number of retorts burning at any one time, thus also minimizing the potential hazards associated with the operation.

During the retort's life, it is subject to four basic activities: access, stoping, rubblization and burning. The general rules governing the interrelated operation of these activities include:

- Main retort development entries are driven to the field boundaries. Retorts are then developed, rubblized and burned, retreating from the field boundary toward the shaft pillar.
- An equivalent of four retorts should be burning at any one time.
- The burning cycle for each retort requires a total of 60 days.

On the basis of these general guidelines, a computer model was developed and used to assure continuity of oil and gas production at the required rate. Computer model results then provided the basis for the derivation of labor and material quantities for the commercial mine operation.

7.3 MINED ROCK PRODUCTION

Initially, all rock will be hoisted up the MDP service-production shaft and will not exceed 2000 TPSD for the first three years. This will increase to the 6000 TPSD full capacity of this shaft in 1982 when commercial underground development begins.

Completion of the full crushing, hoisting and service facilities in 1985 will permit crushed rock hoisting to begin. Mine production is expected to reach a nominal hoisting rate of 40,000 TPSD by 1988.

CHAPTER 8
SUBSIDENCE

It has not yet been determined whether subsidence of the surface over burned out in situ retorts will occur. The geometry of the retorts and intervening pillars has been selected to minimize subsidence potential. Nonetheless, the best way to evaluate the behavior of the completed retort and its overburden is to observe closely any variation in surface topography during the Modular Development Phase (MDP). Refer to Section 6, Chapter 13 for methods of predicting, monitoring and mitigating subsidence.

CHAPTER 9
MAJOR ALTERNATIVES AND SELECTION RATIONALE

The choices for the mining approach to be taken for the development of oil shale are divided into two broad categories. In the first, oil shale is mined by any of a variety of methods and delivered to a retort on the surface. In the second, the shale is retorted in the ground or in situ. The second approach can be further divided into a true in situ method where the deposit is developed totally through drill holes from the surface with no personnel underground, and the Modified In Situ approach where the deposit is prepared by underground mining methods.

Although no commercial oil shale operations have yet been developed in the Piceance Creek basin, experiments have been carried out utilizing underground mining and surface retorting, true in situ recovery and Modified In Situ recovery.

The initial decision of RBOSP was to use open pit mining and surface retorting on Tract C-a. This plan required off-tract waste disposal. A subsequent decision by the Interior Department solicitor found that the land for off-tract waste disposal could not be made available for the Tract C-a project except by act of Congress. This decision was a very serious impediment to the development of the tract by open pit methods. This, plus other unresolved problems, resulted in RBOSP revising its development plan.

The Modified In Situ method produces about one-fifth as much processed shale at the surface than any of the surface retorting approaches, assuming all oil shale mined in the MIS method is surface retorted. This smaller amount of processed shale and a small amount of waste rock from shaft access to the deposit in the Modified In Situ approach permits on-tract waste disposal. The adoption of the Modified In Situ approach lessens the waste disposal problem by leaving about 80% of the processed shale in place after retorting.

The environmental problem posed by large processed shale piles with attendant dust control and revegetation requirements is significantly reduced with the shift to MIS. The visual impact of the MIS development will be less than with open pit mining.

Resource recovery within the interval developed by MIS retorts is dependent on pillar thickness and recovery of the contained resource within the retort. If recovery of resource within the retort is assumed to be 60% of Fischer Assay of the rubblized shale within the retort, then total recovery for the interval would be 36% for a 60-foot pillar and 24% for a 120-foot pillar. These recoveries may be increased if a workable system can be devised to stabilize the spent retorts and then rubblize and retort the intervening pillar. Overall recovery is estimated to be about 20% of the total resource for the MIS operation.

The open pit approach would achieve a higher recovery of the resource dependent on the cutoff grade adopted. An open pit on Tract C-a, as projected by the original planning, yielded a recovery of 65% of the total resource.

A room and pillar mine, although it can achieve a good recovery of the mining interval, is typically limited to a few higher grade intervals. Thus, for the room and pillar development of Tract C-a, overall recovery is projected to be only 14% of the total resource.

In summary, the Modified In Situ method is environmentally preferable to the other methods considered. The adoption of the MIS method does not require off-tract land for waste disposal. It achieves a reasonable recovery of the resource with promise of improvement as experience is gained. For these reasons the method was adopted over the others considered.

SECTION 3
PROCESSING

CHAPTER 1
INTRODUCTION

The first processing step in the conversion of oil shale to useful hydrocarbon energy involves heating the rock to a temperature of about 900^{o} F. This heating process decomposes the high molecular weight organic material contained in the shale into smaller hydrocarbon molecules. Cooling and condensing of these vapors produces an oil product which resembles crude oil in several respects such as boiling range and hydrogen to carbon ratio. This process of heating oil shale and decomposing the contained organic material is known as retorting.

The shale oil product recovered from retorting contains waxy compounds and suspended particles of shale, both of which make the oil difficult to transport in an ambient temperature pipeline. Thus, additional processing steps, called upgrading, are required to prepare the oil for transport from Tract C-a to a refinery where the oil will be converted to marketable products. The processing equipment and support systems required for retorting and upgrading are known as the processing facility.

Section 3 of this Detailed Development Plan describes the processing facility selected for Tract C-a. Anticipated atmospheric emissions are presented together with estimates of fuel, power, and water requirements for the processing facility. Studies of alternative technologies were made to develop the plan and results of these studies are summarized.

1.1 RETORTING

Experimental research and development work on shale retorts have been underway intermittently in the United States since the 1920's. Industrial efforts in other countries date back to the 1850's. During the

first 100 years, emphasis was placed on the development of aboveground retorts, resulting in significant technological advances for this process. Recently, experimental work has been directed toward methods of in situ retorting and favorable results have been obtained.

In keeping with the spirit of the prototype leasing program to determine the feasibility of commercial production, both aboveground and in situ retorting technologies have been considered for development of Tract C-a. The following guidelines were used in choosing among the several developmental retorting processes:

- The retorting process must be capable of continuous operation and give efficient recovery of energy from shale.
- The experimental work for such technology must be sufficiently far advanced to assure a reasonable chance of successful operation of a large scale, commercial-size retort.
- The retorting technology must be available to the developers of Tract C-a either from information in the public domain or by license from patent holders.

Following several detailed screening studies, Gulf Oil Corporation and Standard Oil Company (Indiana) obtained access to both aboveground and modified in situ retorting technologies. With respect to aboveground retorting technology, a licensing agreement was signed with the Tosco Corporation for use of TOSCO technology and Gulf and Standard continued their participation in the Paraho retorting development project. For modified in situ retorting technology, RBOSP used information provided by the Lawrence Livermore Laboratory of the University of California, and data from the Laramie Energy Research Center for studying a Modified In Situ (in place) shale oil recovery plan. Information was also obtained from other ERDA affiliated laboratories for these in situ studies.

RBOSP proposes to develop Tract C-a in two phases - first, a Modular Development Phase (MDP) and, second, a Commercial Phase. The MDP

involves construction and operation of a series of Modified In Situ (MIS) retorts of progressively increasing size, culminating in the demonstration of a commercial-size retort. RBOSP considers the MDP as a sound technical approach to commercial operation on Tract C-a since the anticipated size of a commercial MIS retort is about ten times larger in volume than any in situ retort which has been tested to date. In addition, improvements to the process are expected and these improvements can be included in the commercial operation.

The Commercial Phase involves operation of several commercial-size MIS retorts at a time. The portion of the shale which must be brought to the surface in accordance with MIS technology will be retorted in TOSCO II retorts.

1.2 UPGRADING

Raw shale oil produced from either MIS or TOSCO II retorts requires a minimum amount of upgrading to prepare the oil for pumping through ambient temperature pipelines. The necessity for this minimum upgrading depends on whether the quantity of oil production justifies pipeline shipment. MDP operations will produce about 4000 barrels per stream day (BPSD) during demonstration of a single commercial-size MIS retort. Oil production from smaller MIS retorts will be proportionately reduced. This production is sufficiently small that oil produced during the MDP will be shipped from Tract C-a by truck.

On the other hand, it is not practical to handle by road transport the large quantity (about 76,000 BPSD) of oil produced during Commercial Phase operations. Minimum upgrading to produce pipeline quality oil will then be carried out in order to pipeline the oil product from Tract C-a.

1.3 PRODUCT DISPOSITION

The product disposition plan includes a pipeline to transport the Commercial Phase oil product from Tract C-a to the Rangely terminal of the Amoco pipeline system. This pipeline is described in Section 5, Chapter 4. From the Amoco terminal, it is planned that the oil will enter existing pipeline systems to be conveyed out of Colorado to the point of use as determined by Gulf and Standard. By-product sulfur produced during commercial operations will be trucked to a rail siding in the Rifle area for transportation to market.

1.4 ENVIRONMENTAL CONTROLS

In keeping with the spirit of the prototype leasing program, best available environmental control technology will be used in the processing facility. Systems proposed for use in the Commercial Phase to accomplish gas purification and particulate emission control have been operated previously in oil refinery applications. Operating experience with the shale oil facility will likely lead to improvements in these control devices - a tacit objective of the prototype leasing program. Specific details are given in Chapter 5.5 of Section 6 concerning air quality control.

A zero surface water discharge philosophy has been adopted for the Commercial Phase processing facility to control possible surface water contamination. All waste water streams will be collected, stripped of volatile matter where necessary, and used ultimately to moisturize processed shale. The relatively small amount of contaminated water produced in the MDP will be incinerated in a thermal oxidizer. Water required for both the MDP and Commercial Phase will be supplied from sources beneath Tract C-a, although surface water rights are available as a supplement, if needed. Additional information on water quality control is found in Chapter 6 of Section 6.

1.5 RELATED ACTIVITIES

Production of electric power using low BTU gas produced from MIS retorting as fuel is an important aspect of the planned Commercial Phase operation. This power will satisfy most of the requirements of the commercial processing facility. Other processing-related support facilities, such as steam generation, water treatment, etc., have been selected for the MDP and Commercial Phase based on oil refining technology.

CHAPTER 2

MODULAR DEVELOPMENT PHASE (MDP)
PROCESSING OPERATIONS

2.1 DESCRIPTION OF MDP PROCESSING FACILITY

A. Scope of Processing Facility - The MDP involves construction and operation of a series of MIS retorts of progressively increasing size. This program will culminate in the operation of commercial-size MIS retorts to demonstrate the technical and economic feasibility of this retorting technology. The processing facility includes equipment to supply air and steam to the MIS retorts and to recover oil product. The recovered raw shale oil is shipped from Tract C-a by truck. Gas and water from the retorts are incinerated in a thermal oxidizer.

B. Modified In Situ Retorting (MIS) - The MIS process depends on the underground heating of oil shale using hot fluids. Oil shale deposits are relatively impermeable to the free flow of air and gases. Permeability must be increased by some means in order to efficiently recover hydrocarbon products. "True" in situ processes make use of boreholes from the surface to induce hydraulic fracturing, inject explosives or use some other means to introduce cracks and fissures in the deposit and thereby produce a satisfactory level of permeability. MIS processes feature the mining of a portion of the in-place material and then using explosives to expand the remaining oil shale into the total volume. In this manner a retort of predetermined dimensions and controlled void volume can be produced for better control of retorting conditions. Product collection is more simple and more complete.

A system for introducing combustion air and steam to the top of the retort is installed. Products are collected at the bottom of the retort

and separate gas, water and oil streams are removed through tunnels to the surface.

Retorting is initiated by igniting the top of the rubble using a supplementary fuel or heated air and introducing the steam-air mixture, initially at a low rate. The first several feet of rubble will yield relatively few hydrocarbon products. Most will be consumed by combustion which occurs concurrently with retorting. As the hot combustion gases pass downward through the rubblized shale, the oil shale is heated to retorting temperatures in advance of the flame front. The oil and gas products are driven off, leaving a coke amounting to about 20-25 wt% of the original kerogen. This coke is then combusted when the flame front passes through and is entirely sufficient to provide the heat required for retorting.

Larger blocks of shale retort more slowly because of the greater time required for heat to reach their inner regions. Some part of the oil and gas products from the larger blocks will be released in the presence of oxygen and will burn and provide fuel for the process at the expense of product yield.

As continued flow of combustion air and steam exhausts the coke fuel at the top of the rubblized shale the flame front moves downward, but at a slower pace than the retorting front. Once the flame front has passed a fixed horizontal plane in the bed, no more fuel is available to the combustion air-steam and cooling of the burned shale begins. Eventually the burned portions of the retort approach the temperature of the incoming combustion air-steam mixture. Steam is added to combustion air to allow for modifying the rate of combustion through control of the oxygen concentration to the optimal level. A second purpose of the steam is to increase the thermal efficiency of the process by more effectively removing heat from the burned portion of the retort and adding it to the retorting zone. Finally, through the introduction of steam, use can be made of its reaction with the residual coke to produce H_2 and CO.

The retorting zone produces oil mist and vapor, hydrocarbon gases, hydrogen, carbon dioxide, hydrogen sulfide, ammonia and water. Liquid water produced from retorting and residual groundwater inflow is expected to be of the same magnitude as liquid oil production. Thermal breakdown of mineral carbonates, as well as combustion and retorting, produce carbon dioxide. The products are cooled as they release heat to the shale rubble below the retorting front. The oil and water are largely condensed and flow as liquids to the bottom of the retort where they are collected.

A modular development is planned. Initially, two retorts of dimension 30'x30'x140' high will be burned in sequence. Average void volume will be in the 30% range rather than 20% as planned for commercial scale operations and for subsequent retorts in the development phase because of difficulties in producing lower void fractions in small retorts. These retorts will provide data basic to achieving optimal operating conditions.

Following analysis of the results of the 30-foot square retorts, two retorts 50'x100'x140' high will be prepared in sequence. These retorts will allow refinement of operating conditions, will provide better data on pressure drop through the retorts and will test mining methods planned for full-scale retorts.

Prototype commercial scale retorts, one 100'x150'x400' high and several 150'x300'x700' high are then planned. Again, preparation and burning of the retorts will be in sequence to allow for changes in retort design and operating conditions as optimal operation is approached. Retorts of this scale will be prepared by the sublevel caving method, such that rubble characteristics will accurately represent those expected in full commercial scale operation.

Judgement of the commercial and environmental viability of the project will be based, to a great extent, on the performance of the 100'x150'x400' retort. The remaining prototype retorts will allow for refinement of

techniques while final design and construction of the full commercial operation is completed. They will produce substantial quantities of oil for studies of optimal methods of refining and end use.

MDP retorts will be heavily instrumented to monitor conditions within the retorts, especially temperatures and gas compositions which are indicators of the effectiveness of the retorting.

C. MDP Processing Facility - A flow diagram of the processing facility associated with the commercial-size MIS retorts operated during the MDP is shown in Figure 3-2-1. Air is compressed and piped to the retort together with steam or water. Products from the retort flow to an underground separator where gas is separated from oil and water. The gas flows to a central collection point aboveground, through a wet gas scrubber and then to a thermal oxidizer where the combustible components of the gas are burned. The thermal oxidizer is equipped with a flue gas scrubbing system to control atmospheric emissions.

Oil and water streams from the underground separator are pumped to aboveground settlers. Separated oil is sent to a tank for storage prior to shipment by truck from the tract. Water collected from the settlers is sent to the thermal oxidizer.

Similar equipment, except the wet gas scrubber and gas blower, of appropriate capacity will be provided for smaller MIS retorts operated during the early stages of the MDP.

D. Support Systems - Systems provided to support operation of the processing facility are as follows:

- Water Treatment
- Steam Generation
- Water Chemicals
- Oily Water Treatment
- Plant Air

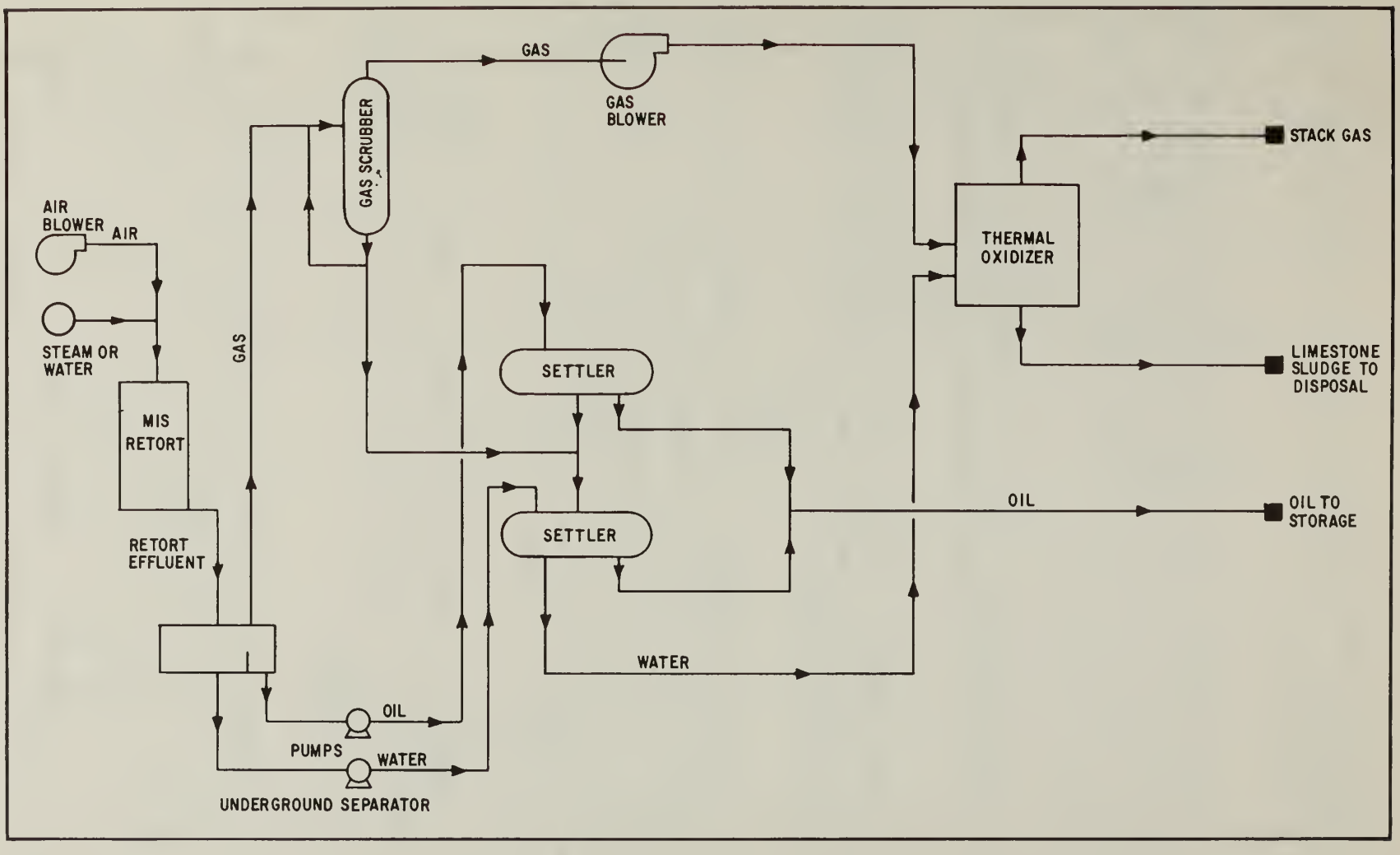


Figure 3-2-1

FLOW DIAGRAM OF MODULAR DEVELOPMENT PHASE PROCESSING FACILITY

- Emergency Electric Power
- Fire Water
- Thermal Oxidizer

1. Water Treatment - Raw water is needed in the processing facility to supply processing, steam generation, and for miscellaneous uses. A lime-zeolite system used to prepare treated water and boiler feed water is illustrated in Figure 3-2-2.

2. Steam Generation - A boiler is provided to supply steam as required for operation of the MIS retorts and for miscellaneous uses.

3. Water Chemicals - Storage, handling, and pumping systems are provided for conventional chemicals used in softening water and for boiler water quality control.

4. Oily Water Treatment - Oily water washed from process plant pads or from accidental leaks is sent to the API separator system, illustrated in Figure 3-2-3, through an oily water sewer. Separated oil is returned to the product recovery plant and water is sent to a retention pond. Any sludge collected in the API separator is periodically removed and burned in the thermal oxidizer.

5. Plant Air - A plant and instrument air system is provided to supply compressed air to the processing facility. Air is compressed, cooled, and stored in a receiver. Part of the air is dried and filtered for instrument air use.

6. Emergency Electric Power - The processing facility for the MDP is supplied with electric power from an outside source. An emergency generator is provided, however, to ensure electric power for essential plant systems in the event of loss of normal power supply.

7. Fire Water - The fire water system provided for the processing facility is connected to the overall project fire water distribution

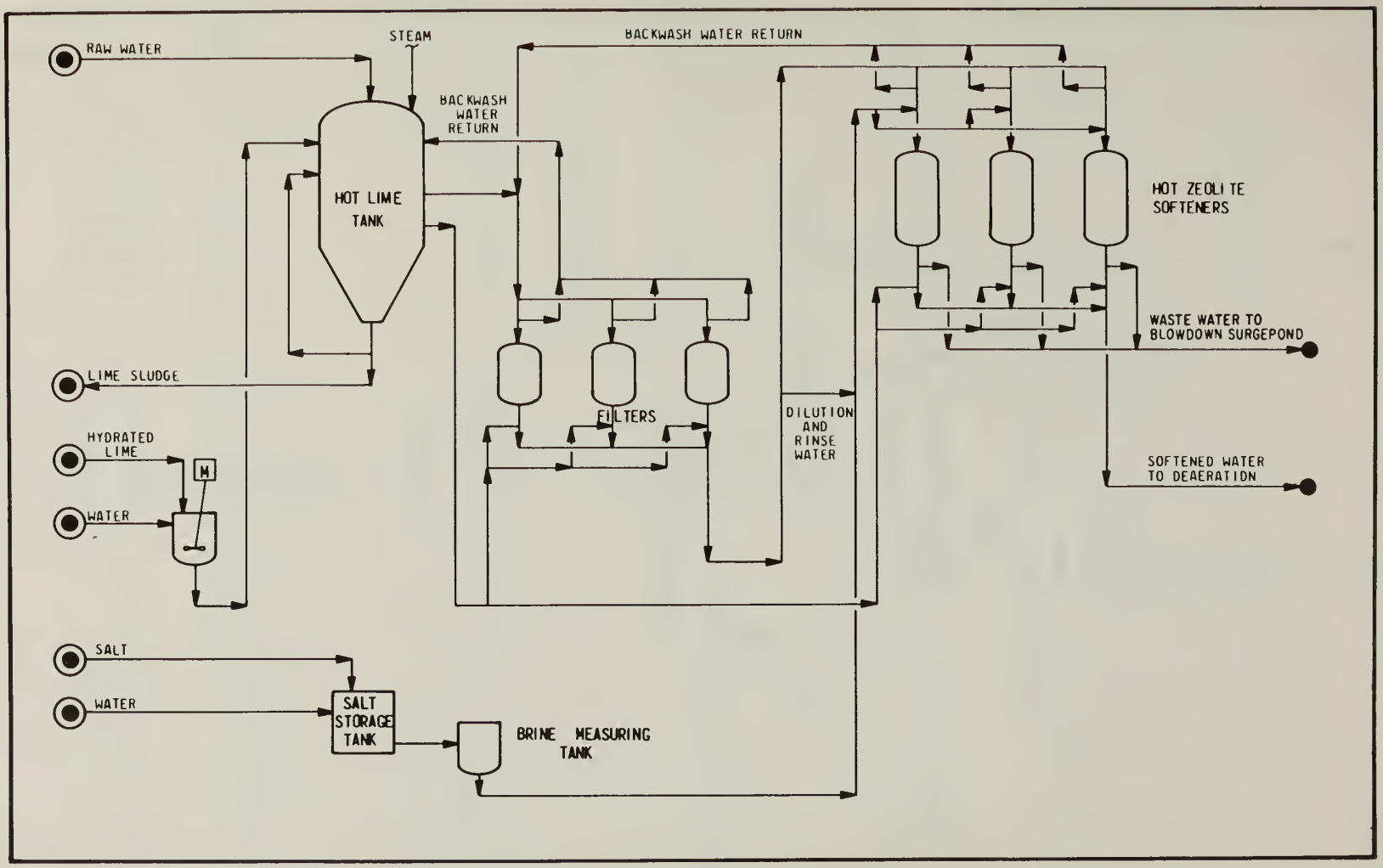


Figure 3-2-2

FLOW DIAGRAM OF SUPPORT SYSTEM - WATER TREATMENT

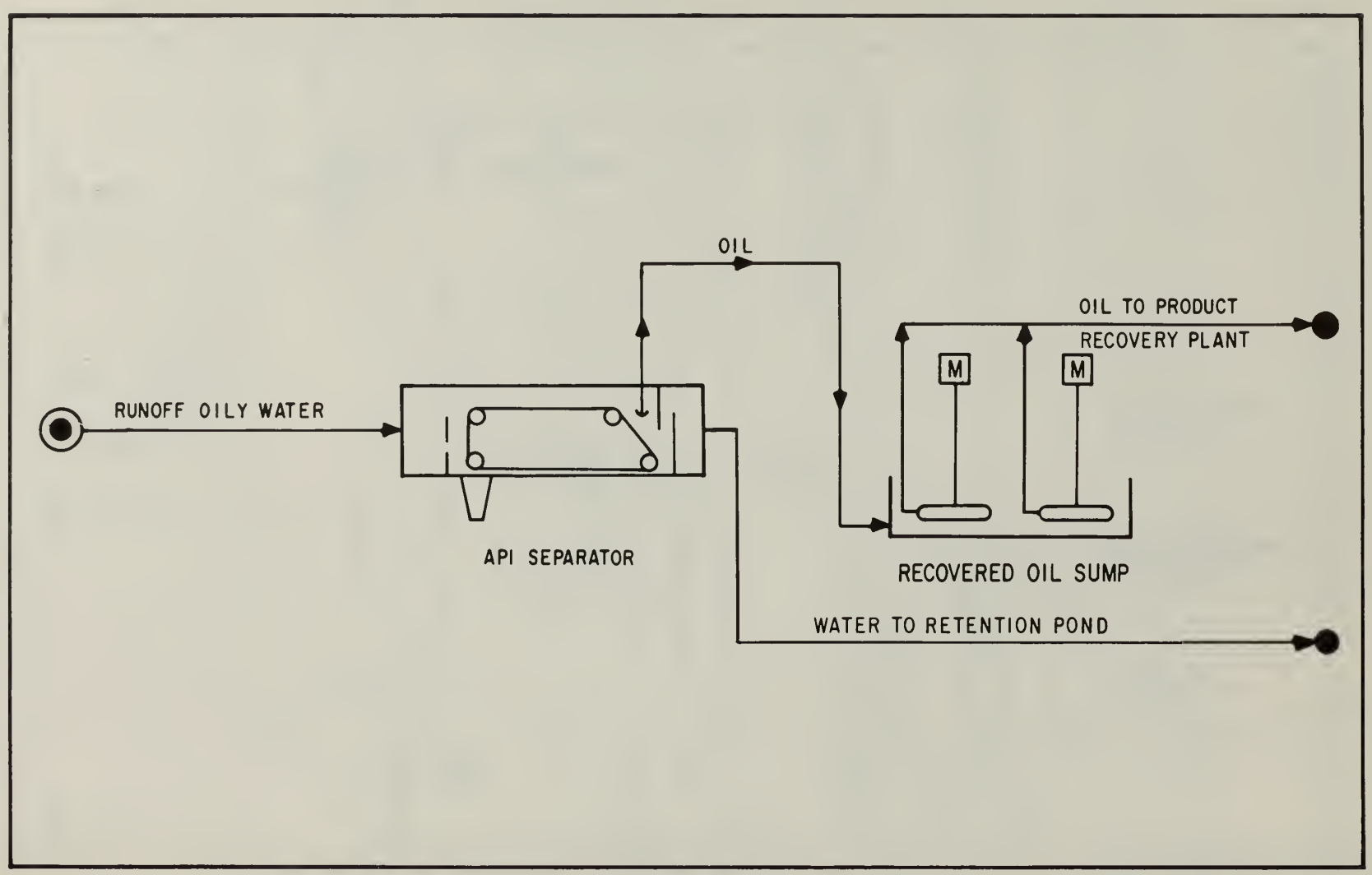


Figure 3-2-3
FLOW DIAGRAM OF SUPPORT SYSTEMS - API SEPARATOR

system. Details are discussed in Section 6, Chapter 3, Fire Prevention and Control.

8. Thermal Oxidizer - Gas produced from the operation of MIS retorts during the MDP together with retorting water and sludge from the API separator, will be burned in a thermal oxidizer system. The thermal oxidizer includes a refractory-lined firebox where combustible materials are burned with an excess of air. Flue gas from the oxidizer is cooled and scrubbed with an alkaline solution before release to the atmosphere to control emissions of sulfur dioxide and particulates.

E. Overall Material Balance - The expected yields of oil and gas from a commercial-size MIS retort operated during the MDP are as follows:

Shale Oil Product, BPSD	4,000
Retort Gas Product, MMSCFD	210

The projected oil and gas yields are based on MIS retorting of shale having an average Fischer assay grade of 23 gpt.

F. Utility Requirements

1. Electric Power - The MDP processing facility will require about 22 megawatts of electric power during operation of a commercial-size MIS retort. Power is used primarily for the operation of air and gas compressors.

2. Fuel - Low sulfur fuel oil will be used in the MDP for operation of the steam boiler. Fuel oil consumption during operation of a commercial-size MIS retort will be about 1000 BPSD.

3. Water Balance - The following summary describes the disposition of water involved in the operation of a commercial-size MIS retort:

	gpm
Output	
Thermal Oxidizer Stack Gas Loss	800
Water in Flue Gas Scrubber Sludge	10
Miscellaneous Losses	40
	850
Input	
Raw Water Intake	460
Water of Combustion	140
Retort Water and Residual Groundwater Inflow	250
	850

2.2 MODULAR DEVELOPMENT PHASE PROCESSING EMISSIONS AND CONTROL

This part of the Detailed Development Plan identifies sources of emissions from the MDP processing facility and describes pollution control techniques applied to these emissions. Additional information on air quality control is found in Chapter 5 of Section 6.

A. Atmospheric Emissions - This section identifies atmospheric emission sources from the MDP processing facility, describes pollution control techniques applied to these sources and estimates emission rates after control. The location of the processing plants and stacks are shown in Figure 3-4-1. Estimates of emissions from the stacks are given in Table 3-2-1.

1. Fuel Source - Fuel is required for the MDP processing facility to operate the steam boiler. Low sulfur fuel oil will be used for this purpose.

2. MIS Retorting - There will be no emissions from a Modified In Situ retort itself, which is a closed system without openings to the atmosphere.

Table 3-2-1

MODULAR DEVELOPMENT PHASE
PROCESSING FACILITY ESTIMATED STACK EMISSION DATA
COMMERCIAL-SIZE MIS RETORT OPERATION

Stack Description	Thermal Oxidizer	Steam Boiler
Stack Location No.	7	8
Stack Height, Ft.(1)	330	330
Stack Diameter, Ft.	21	7'-6"
Stack Gas Parameters		
Gas Flow, LB/HR	1,828,000	206,700
ACFM	644,400	129,800
Molecular Weight	27.2	29.1
Exit Temperature, ^{o}F.	450	700
Moisture, Vol. %	32.8	10.7
SO_2 Content		
LB/HR	371	62
PPM (Vol.)	87	136
LB/MMBTU	0.39	0.28
NO_x Content		
LB/HR	831	62.1
PPM (Vol.)	269	190
LB/MMBTU Fired	0.89	0.28
Particulates		
LB/HR	42	32.8
gr/ACF	0.0056	0.03
Hydrocarbons		
LB/HR	2.3	5.2
Fired Duty, MMBTU/HR	937	226

(1)Measured from grade (6925' elevation)

3. Product Recovery - Oil, gas and water products of retorting are separated in closed vessels. Oil product is shipped by truck from Tract C-a while the gas is burned in a thermal oxidizer. Water recovered from operation of the MIS retorts is sent to the thermal oxidizer.

Gas and contaminated water contain sulfur compounds which are converted to sulfur dioxide in the thermal oxidizer. Flue gas from the oxidizer is scrubbed with alkaline water which absorbs sulfur dioxide, thereby controlling emissions to the atmosphere. Estimates of these emissions during operation of a commercial-size MIS retort in the MDP are given in Table 3-2-1.

4. Support Systems - The only emissions from the support systems are those from the steam boiler which is fired with low sulfur fuel oil. Estimates of these emissions during operation of a commercial-size MIS retort are given in Table 3-2-1.

Tankage for storage of oil product is required for operation of the MDP processing facility. Description of the storage tanks installed for operation of commercial-size MIS retorts is given in Table 3-2-2, together with estimates of tank vapor losses.

B. Disposal of Solid Wastes - The MDP processing facility generates solid wastes from water treatment and flue gas scrubbing. Spent zeolite and lime sludge from raw water treatment and sludge from the thermal oxidizer flue gas scrubber will be sent to an approved disposal site. Estimated quantities of solids in these streams are as follows:

Water treatment spent zeolite	600 #/yr.
Water treatment lime sludge solids	0.2 TPCD
Flue gas scrubber sludge solids	82 TPCD

Additional information on processing solid waste disposal is discussed in Section 6, Chapter 9.

Table 3-2-2

MODULAR DEVELOPMENT PHASE
PROCESSING FACILITY ESTIMATED TANK VAPOR LOSSES
COMMERCIAL-SIZE MIS RETORT OPERATION

Tank Description	Raw Oil Storage	Fuel Oil Storage
Tank Service	Raw Shale Oil	Fuel Oil
Tank Data		
Number	1	1
Dimensions, Ft.	80Ø x 56	30Ø x 40
Capacity, BBL each	50,000	5,000
Type	Cone Roof	Cone Roof
Storage Temp., ^{O}F.	80	55
Avg. Outage, %	50	50
Annual Turnovers	27.5	71.4
Vapor Pressure of Contents, psia	0.025	0.004
Tank Vapor Losses BBL/Yr	68	1

C. Trace Elements - Results of trace element analyses of Tract C-a core samples were reported in RBOSP's Quarterly Progress Report No. 5. Subsequent work has been done on the trace elements and was reported in the Project's 10th Quarterly Progress Report. A portion of this work has dealt with an attempt to account for the fate of trace elements during retorting, and will be summarized here.

Eleven samples taken from the Mahogany, R-4 and R-3 zones were retorted by Tosco laboratories in Golden, Colorado. The retorts were of the Fischer assay type with provisions added for collecting all products. Tosco analyzed fresh and retorted shale for arsenic, boron, cadmium, fluorine, selenium and antimony. In addition, the water and oil were analyzed for arsenic. An analysis for mercury was desired but was not attempted because of its low concentration and because of the high

possibility of contamination of the samples in the Tosco laboratory. All measurements for antimony were below the 5 ppm level and significant balances could not be obtained by the atomic absorption technique used in the analysis. Average concentrations, $\bar{x}$, and their estimated standard deviation, $s_{\bar{x}}$, are summarized in Table 3-2-3.

Table 3-2-3

TRACE ELEMENT BALANCE IN LABORATORY RETORTING

	As		B		Cd		F		Se	
	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$
Raw Shale, ppm	27	3	40	4	1.4	0.04	874	389	11.4	3.4
Retorted Shale, % Raw	95.5	3.5	99.6	1.5	97.9	0.9	96.9	1.0	91.4	1.1

The tabulated values for concentration in the raw shale are averages of 11 determinations and, similarly, the percent recoveries in the retorted shale are all averages of 11 values. The estimated standard deviations for the averages are listed. The standard deviations of the individual measurements are equal to the square root of 11 times these values. One of the measured values for arsenic in retorted shale was 63%, or 2.75 standard deviations from the mean value of 95.5% indicated in the table. When this apparent outlier is omitted from the data set, the average recovery of arsenic in the retorted shale becomes 98.74% with estimated standard deviation of the mean of 1.5%. The weight ratio of retorted shale to raw shale for these samples averaged 82.5%.

For the full set of 11 arsenic samples the average percentage recovered in the oil was 3.2 and the average percentage recovered in the water was 0.09. The estimated standard deviations of these averages were 0.36% and 0.02% respectively. Arsenic in the gas product could not be measured because of low concentration and the small size of the gas samples.

This set of data shows that the trace elements considered tend to be concentrated in the processed shale in preference to the gas, oil and water products. It is apparent that very little arsenic leaves the retort in the gas stream. Compound types are not identified in this type of analysis. As a result, the degree of toxicity, solubility and other characteristics of the compounds bearing the trace elements cannot be assessed by these methods.

3.1 DESCRIPTION OF COMMERCIAL PHASE PROCESSING FACILITY

A. Scope of Processing Facility - The Commercial Phase processing facility involves retorting oil shale to produce about 76,000 BPSD of pipeline quality shale oil together with elemental sulfur by-product. The individual processing operations and their interrelationships described in the following sections represent the general concept of Commercial Phase processing in the light of the present state of the art.

The processing operations shown in Figure 3-3-1 involve a combination of MIS and aboveground retorting of oil shale having an average Fischer Assay grade of about 23 gallons per ton (GPT) to produce oil which can be pipelined from Tract C-a in an ambient temperature pipeline. Elemental sulfur is produced as a by-product of retorting and oil recovery operations. Electric power is generated, using MIS product gas as fuel, to supply requirements of the processing facility. Plants included in the processing facility are shown in Table 3-3-1, together with their nominal capacities.

Table 3-3-1

COMMERCIAL PHASE PROCESSING PLANTS

Plant	Nominal Capacity
MIS Retorting	134,000 TPSD
TOSCO II Retorting	36,000 TPSD
Oil-Gas Recovery (MIS)	47,000 BPSD
MIS Gas Purification	10,000 BPSD
Oil Recovery (TOSCO)	19,000 BPSD
Oil Fractionation (MIS)	47,000 BPSD
Oil Upgrading and Blending	76,000 BPSD
High BTU Gas Plant	30 MM SCFSD
Foul Water Stripping	-
Sulfur Recovery (TOSCO)	170 LTPSD
MIS Gas Purification (Sulfur Product)	100 LTPSD
Power Generation	230 Megawatts

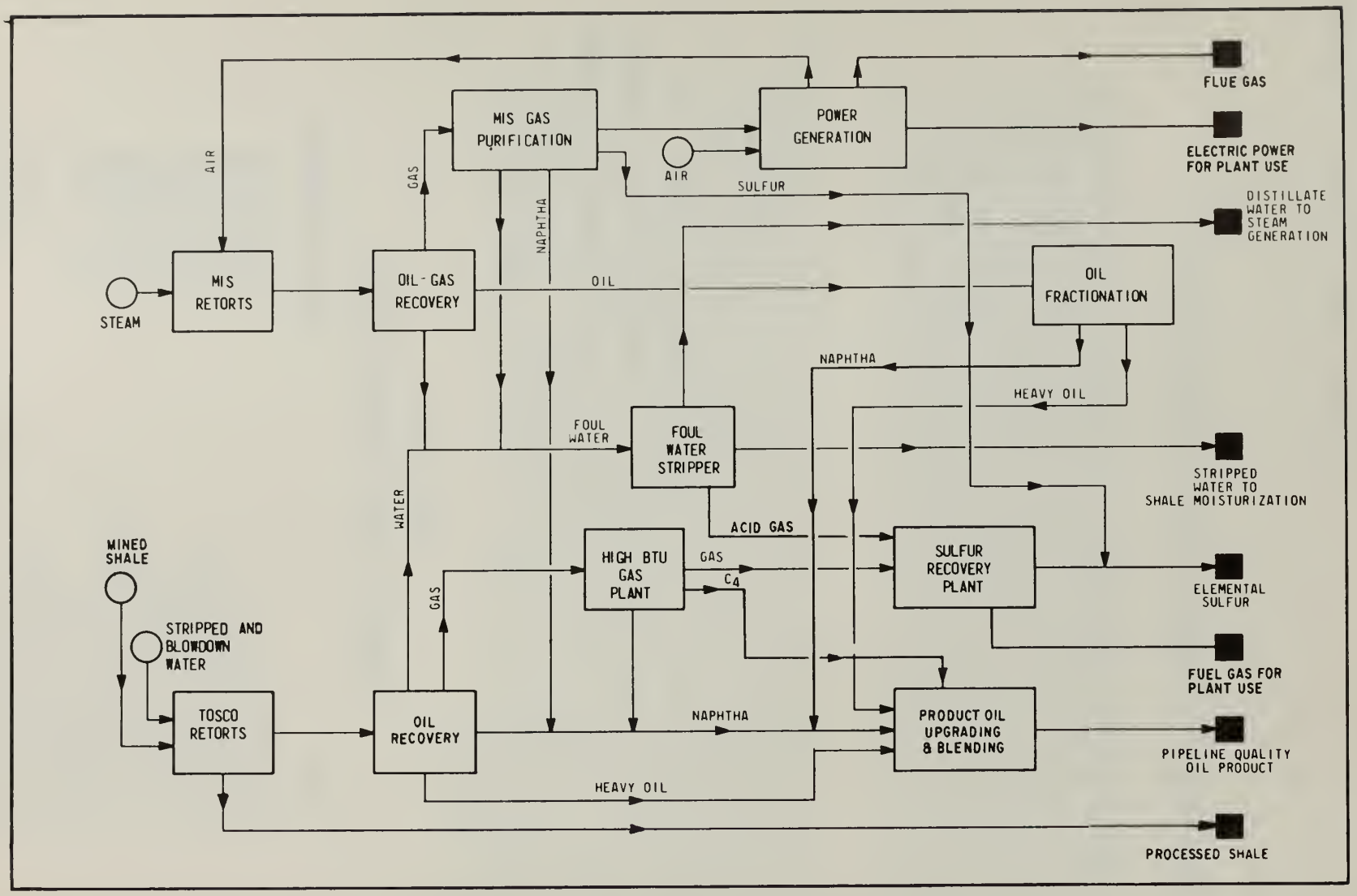


Figure 3-3-1

FLOW DIAGRAM OF COMMERCIAL PHASE PROCESSING FACILITY

Air and steam are injected into MIS retorts which have previously been prepared by mining and rubblization techniques. MIS retorting is accomplished by heating rubblized shale to retorting temperatures with hot gases formed by combustion of a portion of the oil shale. Oil, water and low BTU gas flow from the retorts to the oil-gas recovery plant. The oil is then fractionated to produce naphtha and heavy oil fractions. The gas is first purified of sulfur compounds and then used as fuel to produce electric power.

Preparation of MIS retorts requires removal from the ground of about 20% of the rubblized shale in order to provide satisfactory retorting conditions. Shale brought to the surface is retorted in a TOSCO II retorting plant. The TOSCO oil and high BTU gas are sent to the raw oil recovery plant where gas, naphtha and heavy oil streams are separated. Gas is sent to the high BTU gas plant where a fuel gas is prepared for purification in the sulfur recovery plant.

Naphtha and heavy oil from surface and underground retorting are sent to the oil upgrading and blending plant. Heavy oil streams are treated as required with a flow-improving chemical and then blended with naphtha and C_4 fractions to produce an oil product which can be pipelined from Tract C-a.

Foul waters recovered from the retorting operations are steam stripped in the foul water stripping plant. Stripped water is reduced in volume by evaporation and then used ultimately to moisturize processed shale. The distilled water is recycled to steam generation. Acid gas from the steam stripping operation is sent to the sulfur recovery plant.

B. Retort Feedstock Preparation - The retort feedstock preparation facilities are designed to provide 12,000 TPSD of minus 3/8-inch crushed oil shale for each TOSCO II retort. The major items of equipment included in these facilities are vibratory pan feeders underneath the primary crushed stockpile, covered conveyor belts for transfer of materials from one location to another, enclosed secondary crushing and screening equipment, an enclosed 10-hour capacity storage bin, and an open 24-hour capacity reserve storage pile.

A pictorial flow sheet of the retort feedstock preparation facility is shown in Figure 3-3-2. This operation extends from the vibratory feeders located underneath the primary crushed ore stockpile to the feed hopper near the middle level of the TOSCO II retorts. The retort feedstock preparation facility, which is located to the east of the TOSCO II retorts, will occupy approximately 20 acres. The plot plan for the retort feed preparation facility is shown along with other facilities on the Site Plan Figure 3-4-1.

1. Reclaim From Primary Storage - The primary crushed ore stockpile was described in Section 2, Chapter 6, of this development plan. The facilities include a set of parallel underground conveyor belts which are fed by vibratory pan feeders. Either of the two reclaim belts can be used to feed the secondary crushers. A vibratory pan feeder is located near the edge of the primary crushed ore stockpile, so that ore may be reclaimed by bulldozing equipment. The reclaim belts carry the primary crushed ore to the retort feedstock preparation plant delivery conveyor belt. Transfer points are fully enclosed and dust will be controlled by baghouse suction.

2. Retort Feedstock Preparation Plant - The retort feedstock preparation plant equipment will be housed in a metal building equipped with a baghouse to control dust generated in the crushing and screening operation. Included in the building will be a feed hopper, impact-type crushers, single deck vibrating screens and attendant feeders, and recycle conveyors.

Primary crushed ore will be conveyed from the primary stockpile to the feed hopper at the top of the crushing building. Material will be reclaimed from the feed hopper by vibrating feeders with grizzly sections. About 24% of the primary crushed ore is expected to be 1" and smaller. About one half of this 1" and smaller material will pass through the feeder grizzly and fall directly to the recycle conveyor system for delivery to the screens. The remainder of the primary crushed ore will be discharged into the impact-type crushers. The material from the

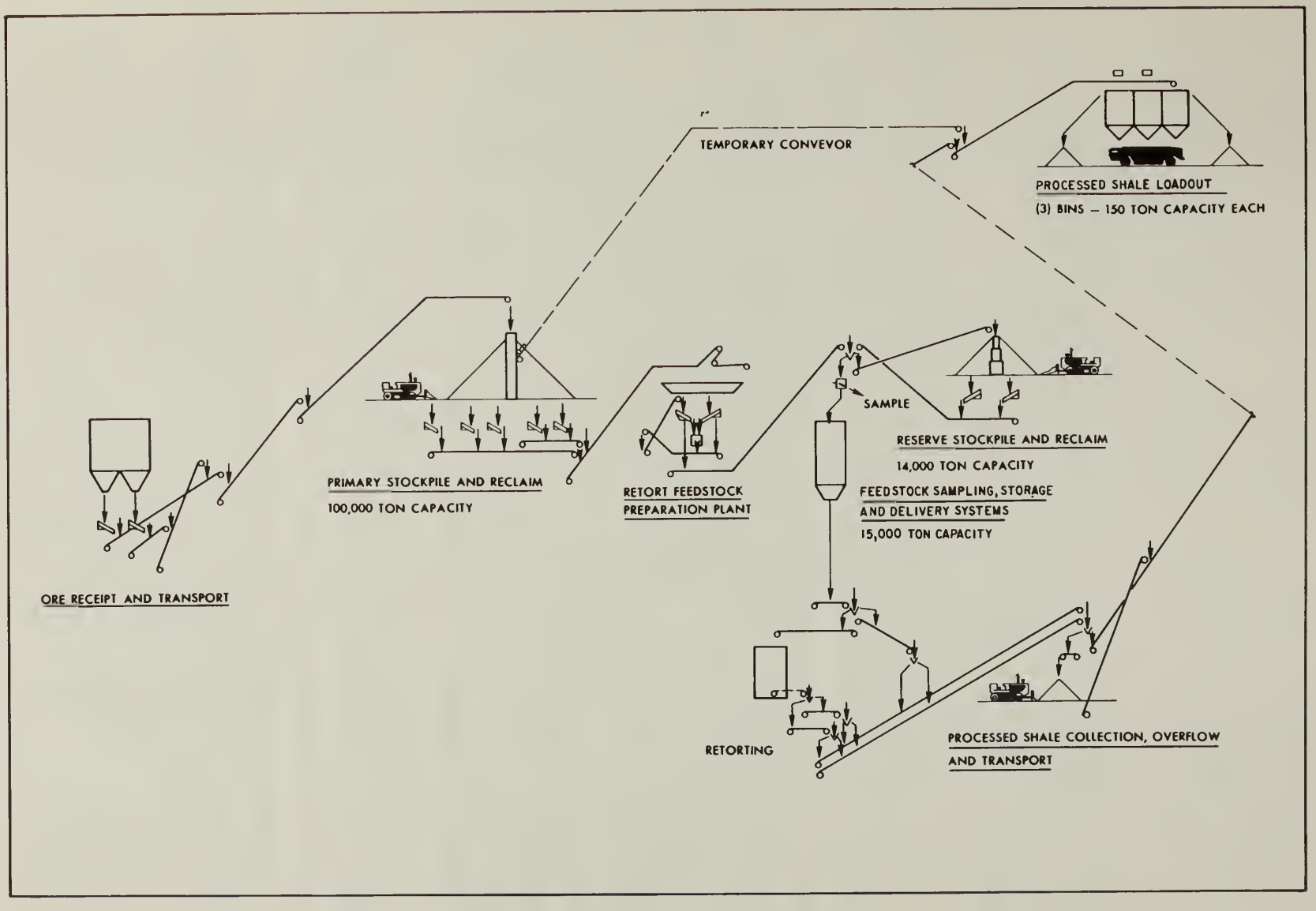


Figure 3-3-2
RETORT FEEDSTOCK PREPARATION FACILITY

crushers fall onto the recycle conveyor system and is delivered to vibrating single-deck screens. Material size for retort feedstock (3/8" and smaller) passes through the screen and is collected by the feedstock delivery conveyor for transportation to the retort feedstock storage bin. Material larger than 3/8" is discharged into the impact crushers and recycled. The closed-circuit crushing and screening systems will produce 84,000 tons per week of 3/8" and smaller feedstock for each TOSCO II retort. Each circuit will operate 18 shifts per week and undergo maintenance 3 shifts per week. This schedule simulates 6 operating shifts followed by one maintenance shift.

3. Transport and Storage - A 15,000 ton capacity retort feedstock storage bin provides for continuous operation of the three TOSCO II retorts. The enclosed storage bin will have the capacity to allow the retorts to be fed for approximately 10 hours while maintenance is being performed on the retort feedstock preparation equipment. The retort feedstock delivery belt will discharge feedstock into a chute at the top of the storage bin. The feedstock will be either delivered to the storage bin and sampling system or diverted to a reserve stockpile. The reserve stockpile contains 14,000 tons and will be provided with a telescopic chute to minimize dust. Feedstock will be reclaimed from beneath the center of the reserve pile with a vibrating feeder and conveyed back to the top of the enclosed storage bin. All transfer points within this system will have baghouse connections for dust control.

The purpose for this outdoor reserve storage pile is three-fold. First, RBOSP wishes to determine if outside storage of retort feed will create operability problems in the TOSCO II retorts. Second, other effects attributable to exposure to the atmosphere need to be determined. The atmospheric emission effects of creating an outside pile of small particles and withdrawing retort feed from it are not known, nor are the effects of long-term storage of small particles related to wind erosion or spontaneous combustion of the hydrocarbons. Third, at the completion of construction, equipment and crushing performance tests will be required to release the vendors from contractual obligations. During that time

it may be necessary to stockpile additional amounts of crushed retort feed. Cleared ground is provided immediately adjacent to the reserve stockpile for this purpose. An additional 63,000 tons of minus 3/8-inch retort feed may be stored in this manner. The ore will be withdrawn from this stockpile during the early operations.

4. Retort Feedstock Sampling System - The lease for Tract C-a provides for royalty payments based on the shale oil content of the retort feedstock. Although there are no established standards for oil shale, sampling can be done in a manner similar to that used in the coal industry. Sampling facilities of this type are included for the development of Tract C-a. In addition, weigh-belts will be installed in front of the retorts to complete the data needed for royalty determinations.

In the enclosure at the top of the retort feedstock storage bin, a sample cutter will take samples of the crushed retort feedstock as it falls from the end of the belt. The gross sample passes through a splitter which rejects most of the sample before feeding the remainder to a sample crusher. After the sample is crushed, the smaller particles again pass through a splitter and a small representative sample is collected once per shift and analyzed by an approved assay method such as the Modified Fischer Assay. All "sample reject" will be returned to the enclosed storage bin. Since the sampling system will be enclosed at the top of the storage bin, primary dust control will be by the baghouse attached to this enclosure. No water spraying will be done because one of the laboratory tests conducted will be to determine surface moisture content of the retort feed.

5. Reclaim and Retort Feed - Retort feedstock will be reclaimed from the enclosed storage bin by gravity flow to three belt feeders and will be transported to the retort modules by three belt conveyors. Because of the possibilities of spontaneous combustion resulting from extended storage of small ore particles, an unloading belt conveyor has been provided for emergency emptying of the storage bin. This conveyor places the feedstock on the processed shale conveyor system for disposal.

Baghouses will provide particulate emissions control for the reclaim and feed systems.

6. Atmospheric Emissions - The only atmospheric emissions expected from the retort feedstock preparation facilities are particulates, or shale dust. These emissions are expected to be generated at points in the system where a transfer is made, e.g., transferring from the end of one belt to the start of the next, transferring into a pile or surge bin, or transferring from the crusher to the belt. Three basic concepts have been adopted to reduce these particulate emissions:

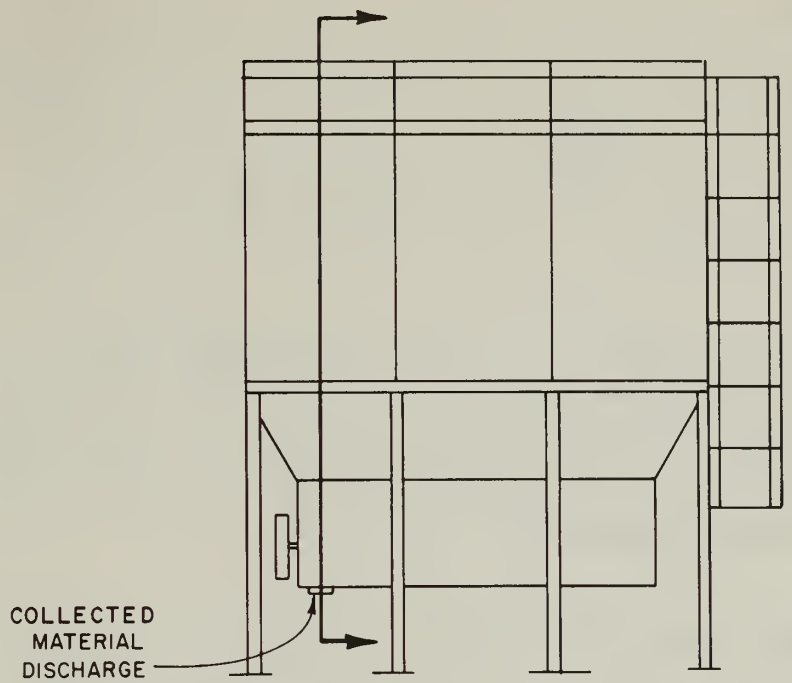
- Covered conveyor belts to eliminate particulate emissions caused by the wind.
- Water sprays at selected transfer points to prevent surface dust from becoming airborne.
- Induced-draft fans and baghouse filters for selected transfer points and the crushing buildings.

These control measures are discussed further in Section 6, Chapter 5.

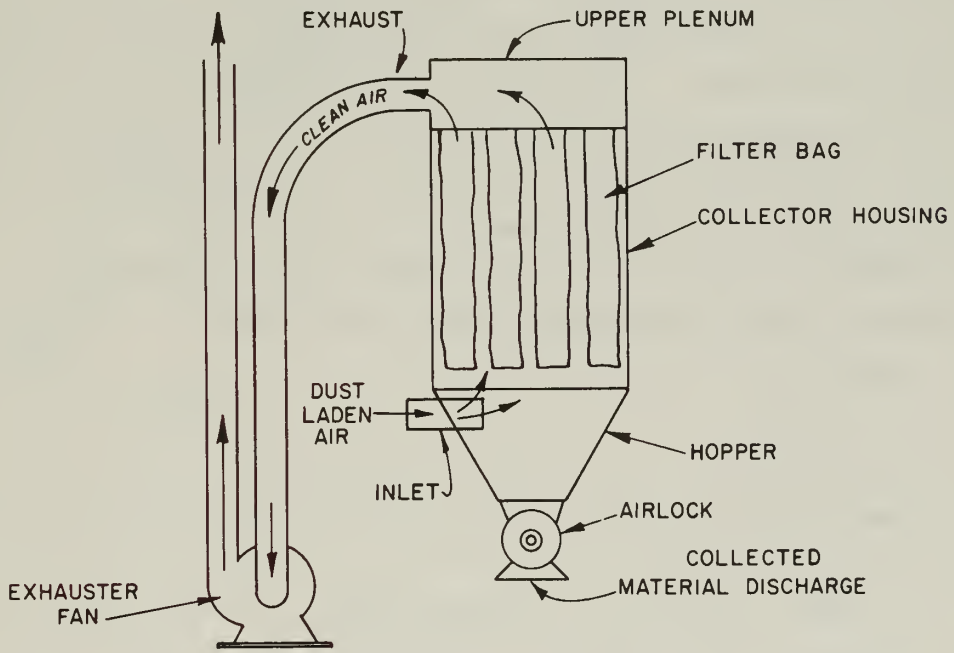
A simplified drawing of a baghouse filter is shown in Figure 3-3-3. A blower taking suction at the top of the baghouse draws dirty air into and through bag-type filters. The air flows through the holes in the filters, but most of the dust particles are trapped by the filters and do not escape through the blower. The dust collected is periodically removed and either placed back on the conveyor or slurried to the processed shale moisturizer. Baghouse filters are considered the best available technology for reducing particulate emissions for this particular application.

C. Retorting

1. Modified In Situ Retorting - Commercial Phase MIS retorts will be prepared and operated as described in Chapter 2. Operating conditions will be adjusted according to experience gained during the MDP. Retorting



ELEVATION OF TYPICAL BAG HOUSE



TYPICAL SECTION THRU BAG HOUSE

FIGURE 3-3-3

TYPICAL BAGHOUSE

rates of up to 14 feet per day are anticipated. Three retorts would be operating at maximum rate, a fourth being started up and a fifth retort being shut down. Anticipated production of liquid oil from the retort product collection system is 47,000 BPSD. An additional 10,000 BPSD will be recovered in the gas purification section giving a total MIS production rate of 57,000 BPSD.

Air supply to the burning retorts will be shut off whenever either oxygen breaks through or temperature of the off-gas becomes excessive. Steam or inert gas may be injected at this time in order to retort the remainder of the retort and at the same time cool it in preparation for possible injection of slurry backfill.

2. TOSCO II Retorting - The oil shale retorting process known as the TOSCO II process is a proprietary process of the Tosco Corporation. A flow diagram of the process is shown in Figure 3-3-4. Raw oil shale, which has been withdrawn from the MIS retorts and crushed to minus 3/8-inch particles, is pre-heated by direct heat exchange with hot flue gas from a ceramic ball heater. Preheated shale is separated from the flue gas in settling chambers and cyclones and sent to a rotating drum retort. Hot flue gas is incinerated within the preheat system to reduce trace hydrocarbon concentration to less than about 90 ppm. Flue gas from the preheat system is passed through a high energy venturi scrubber to remove shale dust and sulfur dioxide before being vented to the atmosphere at a temperature of about 130^{o} F.

Retorting is accomplished in the rotary drum by solid to solid heat exchange between preheated shale and hot ceramic balls, evolving shale oil vapors which are separated from the mixture of balls and processed shale and processed in the raw oil recovery plant. Processed shale is then separated from ceramic balls by a rotating trommel screen. Warm flue gas from a steam superheater is used to remove residual dust from the ceramic balls which are then circulated back by means of a bucket elevator to the ball heater where they are reheated and returned to the retorting drum. Dust removed from the ceramic balls is separated from the flue gas by a high energy venturi scrubber.

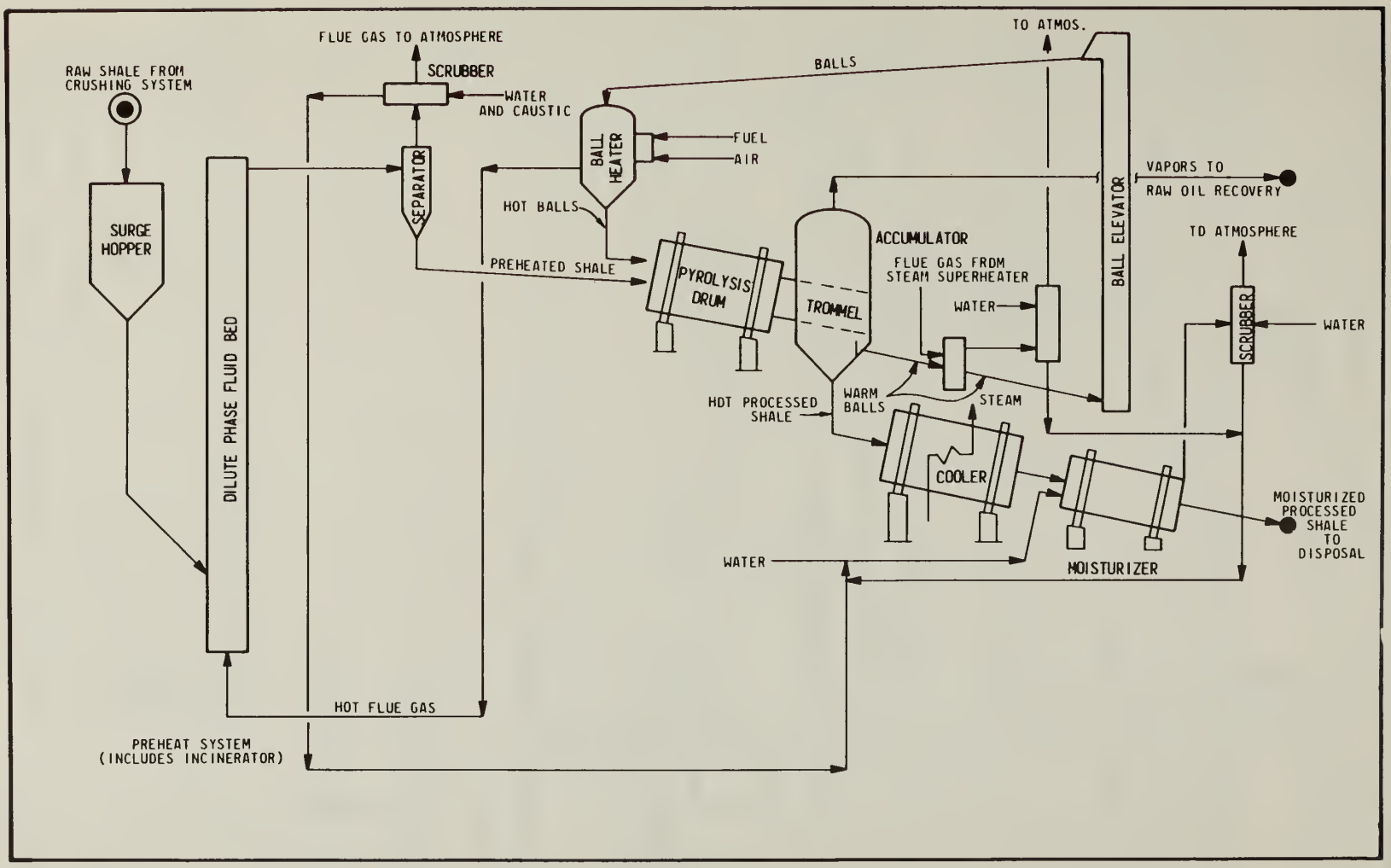


Figure 3-3-4

FLOW DIAGRAM OF TOSCO II RETORTING PLANT

Processed shale is cooled in a rotary drum cooler and is then conditioned for disposal by moisturizing with waste processing water to a water content of about 14 percent. Shale dust incidentally produced in the moisturizing operation is trapped in a venturi wet scrubber.

3. Overall Retorting System - The overall retorting system used for the Commercial Phase operation consists of MIS retorts and TOSCO II retorts. This combination of retorting technolgies has several significant advantages, namely:

- MIS retorting provides a means of recovering oil from shale while leaving in place approximately 80% of the shale to be retorted.
- Since only about 20% of the shale is removed from the ground, the extent of surface processing facilities is reduced compared to operations where all the shale is retorted on the surface.
- The TOSCO II retorting process produces high yields of oil from shale and, in addition, produces high BTU gas which can be effectively purified for use as fuel in the processing operations.

These and other considerations are discussed further in Chapter 5 of this section.

D. Product Recovery

1. MIS Retorting

a. Oil-Gas Recovery Plant - A flow diagram of the plant is shown in Figure 3-3-5. Effluent from the MIS retorts flows to an underground separator where a rough separation of oil, gas and water is obtained. Gas is sent to a scrubber system aboveground where it is contacted with a circulating water stream to remove entrained dust and oil particles. Scrubbed gas is purified for use as fuel for electric power generation.

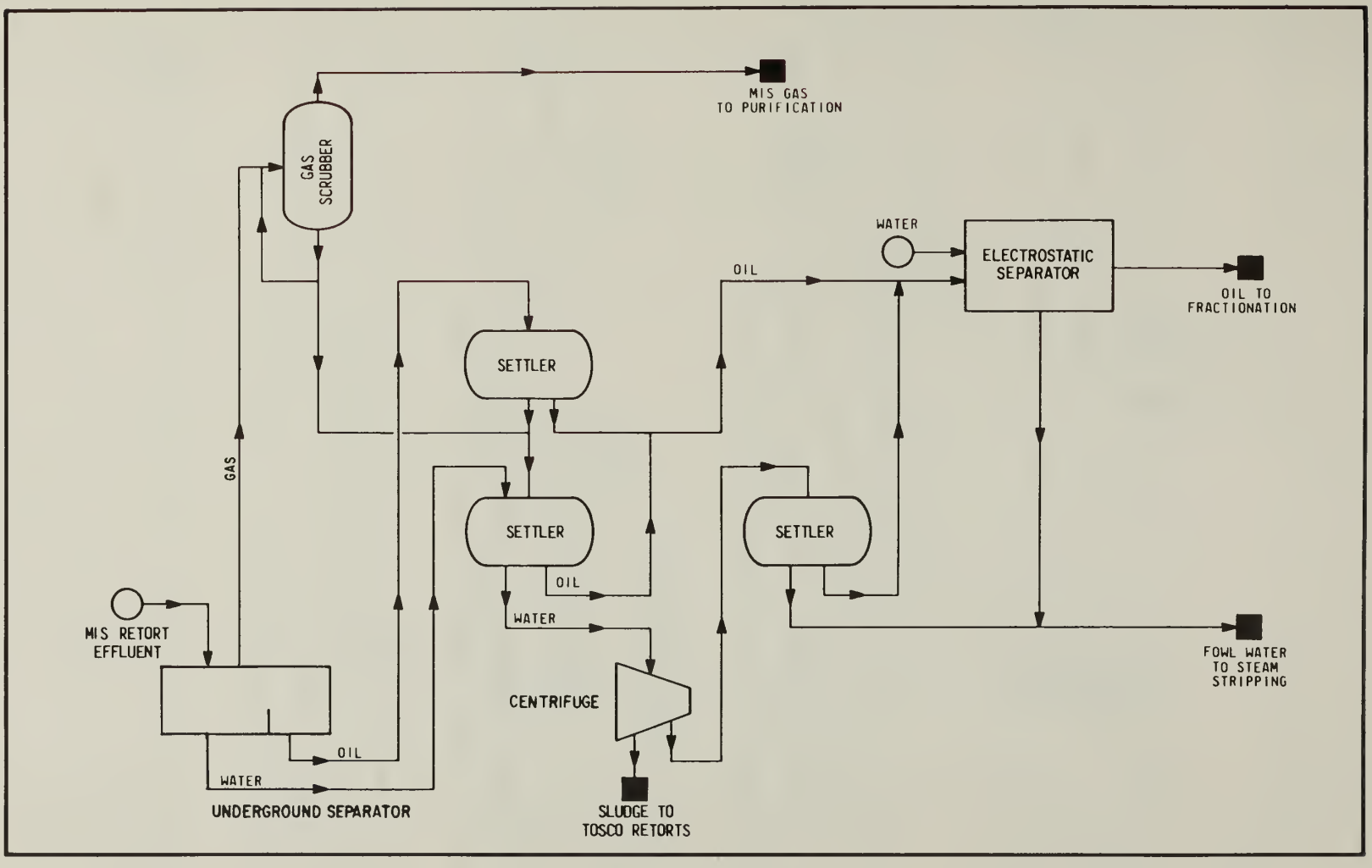


Figure 3-3-5

FLOW DIAGRAM OF MIS OIL-GAS RECOVERY PLANT

Oil and water streams from the underground separator are sent to settlers aboveground where further separation of phases occurs. The water phase is centrifuged to obtain final separation of oil from water. Water from the centrifuge effluent settler is sent to the foul water stripping plant.

The oil phase is sent to an electrostatic separator system where final removal of entrained water and shale dust is obtained. Clarified oil is sent to the oil fractionation plant. Sludge streams withdrawn from the centrifuge and electrostatic separation systems are recycled to the TOSCO II retorting plant.

b. Oil Fractionation Plant - Oil recovered from the oil-gas recovery plant flows to a fractionation plant shown in Figure 3-3-6. Oil is separated into naphtha and heavy oil fractions which are sent to the oil blending plant. Foul water collected in the fractionator reflux drum is sent to the foul water stripping plant.

2. TOSCO II Retorting

a. Raw Oil Recovery Plant - The raw oil recovery plant is designed to separate shale oil produced by the TOSCO II retorting plant into several fractions as required by the Commercial Phase oil upgrading method. A flow diagram of the plant is shown in Figure 3-3-7.

Vapors from the TOSCO II retorting plant are charged to a fractionation system where the raw shale oil is separated into gas, naphtha, gas oil, and residue streams. Gas is sent to the high BTU gas plant while naphtha and gas oil are sent to the oil blending plant.

Shale oil residue from the fractionation system contains solids, primarily shale dust, carried over from the TOSCO II retorting plant. These solids must be removed before the residue can be blended into the oil product in order to avoid pumping and storage problems associated with high solids oil. Solids separation is accomplished in a continuous flow

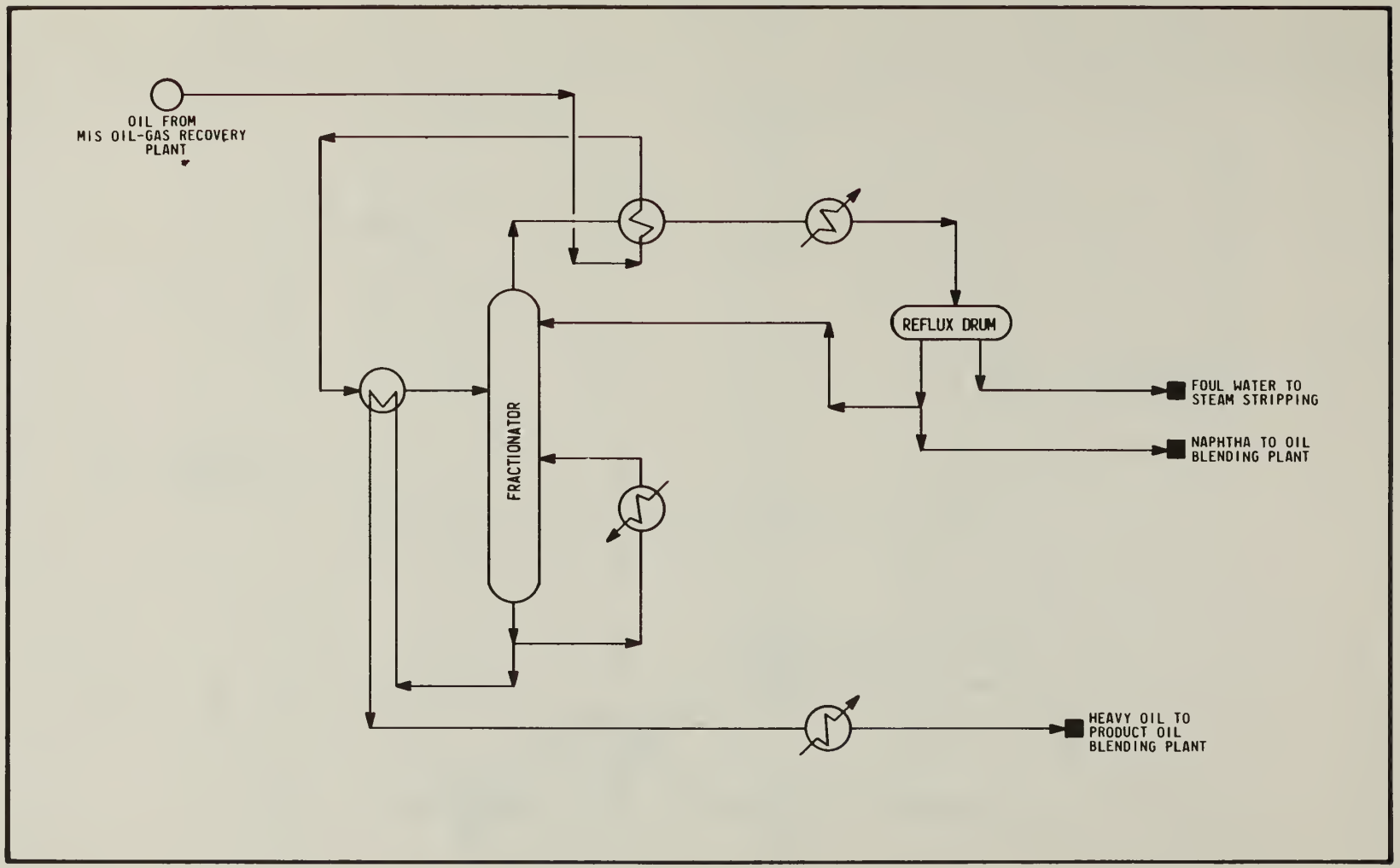


Figure 3-3-6

FLOW DIAGRAM OF MIS OIL FRACTIONATION PLANT

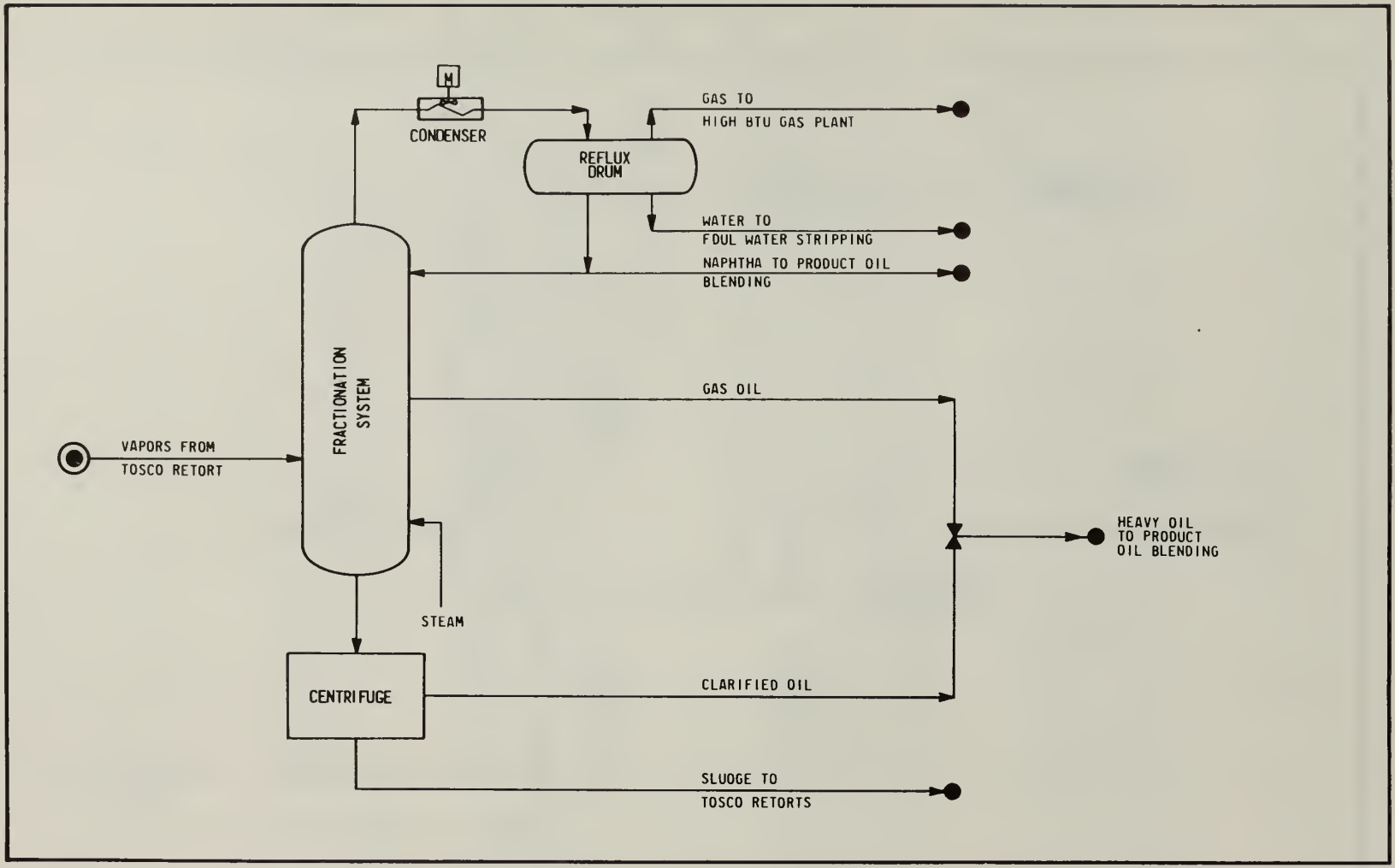


Figure 3-3-7
FLOW DIAGRAM OF RAW OIL RECOVERY PLANT

centrifuge. Clarified oil is sent to the oil blending plant while sludge from the centrifuge, containing solids and some associated oil, is returned to the TOSCO II retorting plant.

b. High BTU Gas Plant - Gas from the fractionator of the raw oil recovery plant is sent to the high BTU gas plant to separate light naphtha and C_4's and to prepare a C_3 and lighter gas stream for subsequent use as fuel gas. A flow diagram of this plant is shown in Figure 3-3-8. Gas is compressed and charged to an absorber where propane and heavier components are absorbed. Rich oil from the absorber is debutanized. Lean oil is recycled to the absorber while the C_3-C_4 fraction is depropanized. The C_3 fraction from the depropanizer is recycled to the absorber for further removal of C_4's. The recovered light naphtha is sent to product oil blending.

The absorber overhead gas flows to the sulfur recovery plant for removal of sulfur compounds. The C_4 liquid fraction is sent to product oil blending. Foul water is sent to steam stripping.

c. Foul Water Stripping Plant - Water collected from retorting, oil recovery, and MIS gas purification operations is stripped of dissolved hydrogen sulfide and ammonia in a reboiled stripping tower as illustrated in Figure 3-3-9. Gas from the stripper is sent to the sulfur recovery plant. Stripped water is heated and evaporated to produce a residual water stream for processed shale moisturization. Distillate water is recycled to the water treatment plant.

d. Sulfur Recovery Plant - Gases recovered from the high BTU gas plant and foul water stripper are treated in the sulfur recovery plant to minimize release of sulfur compounds to the atmosphere. A flow diagram of the plant is shown in Figure 3-3-10.

Gas from the high BTU gas plant contains sulfur compounds produced in the TOSCO II oil shale retorting process. These sulfur compounds are removed from the gas in a scrubbing system based on the Sulfinol Process

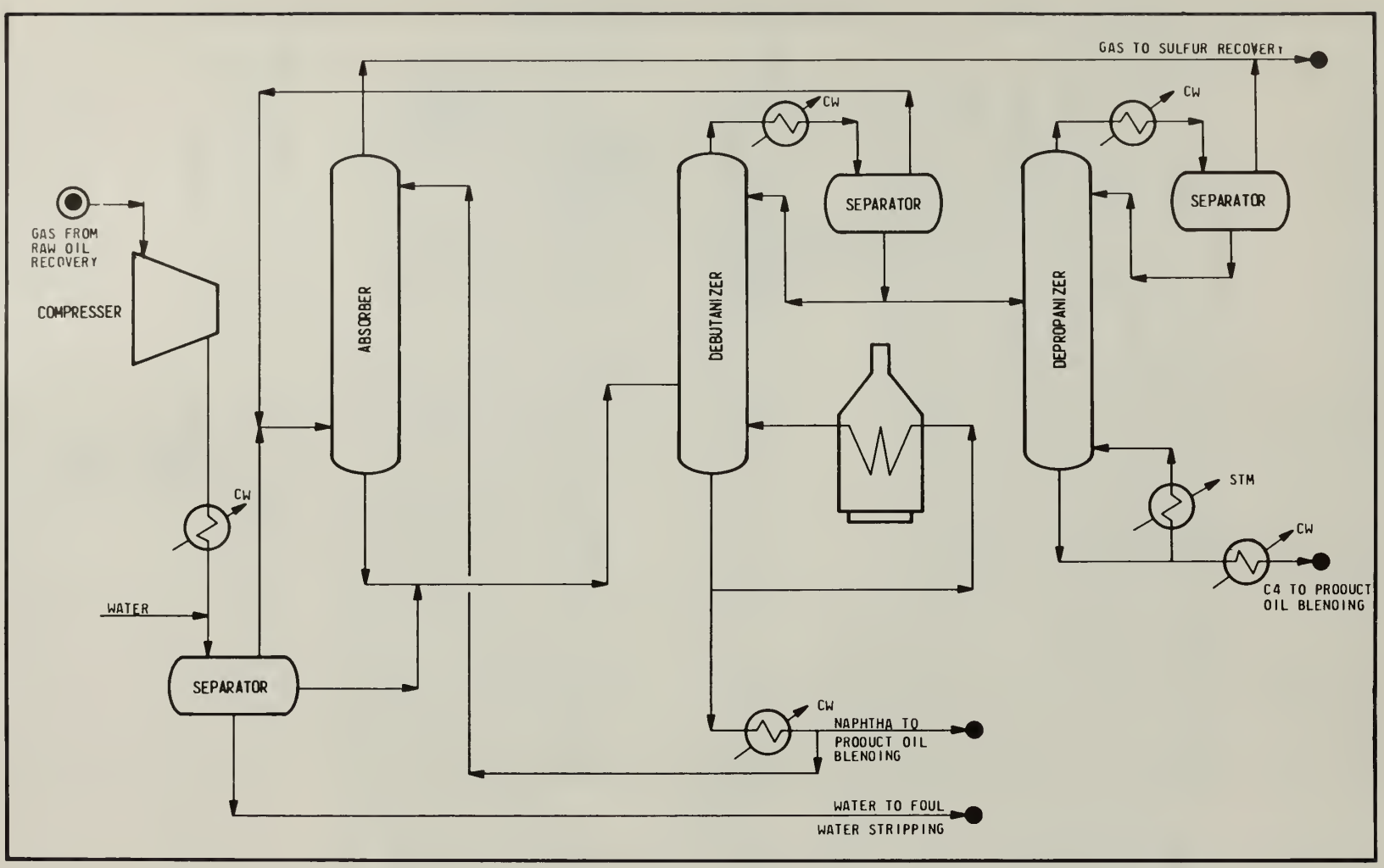


Figure 3-3-8

FLOW DIAGRAM OF HIGH BTU GAS PLANT

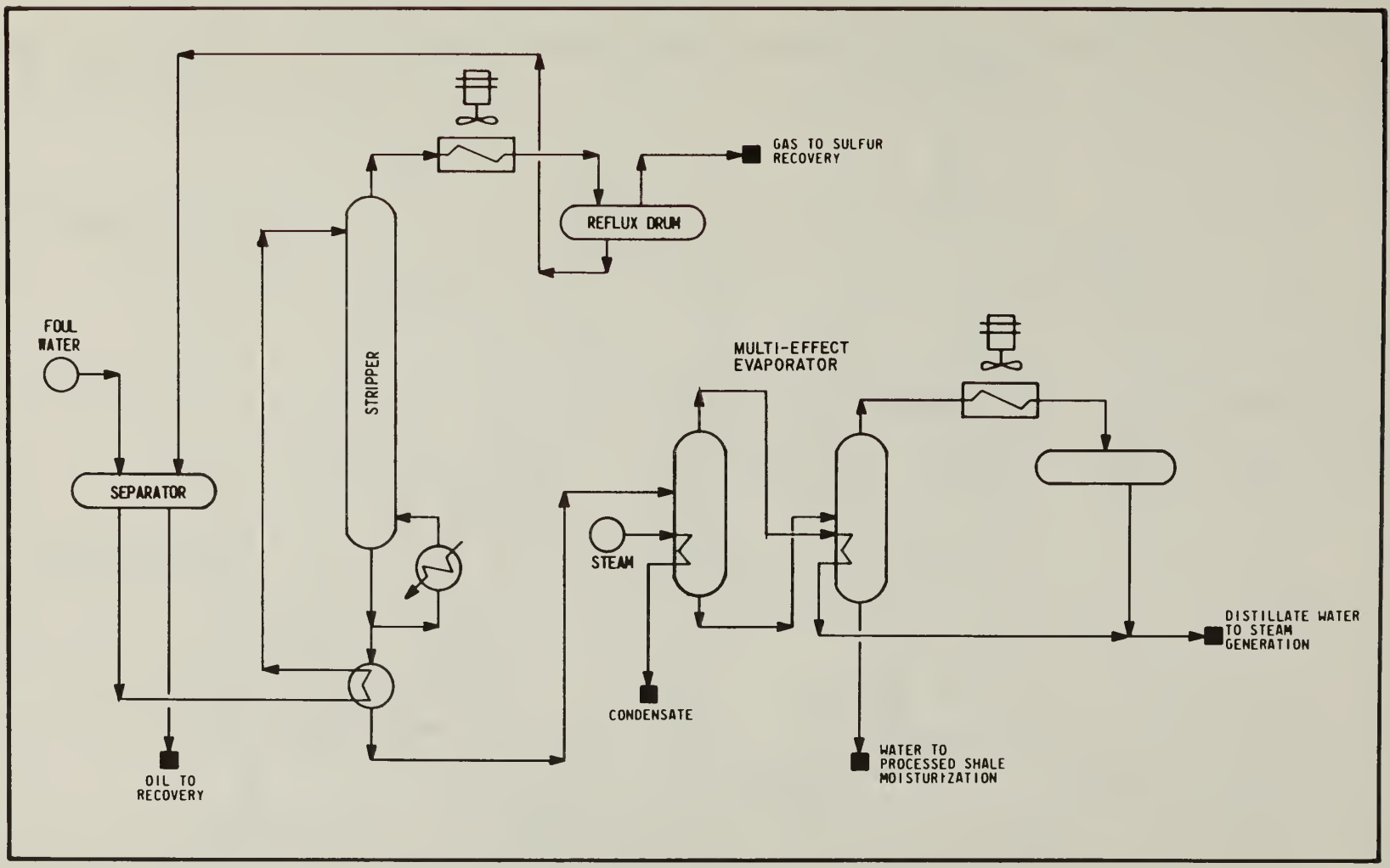


Figure 3-3-9
FLOW DIAGRAM OF FOUL WATER STRIPPING PLANT

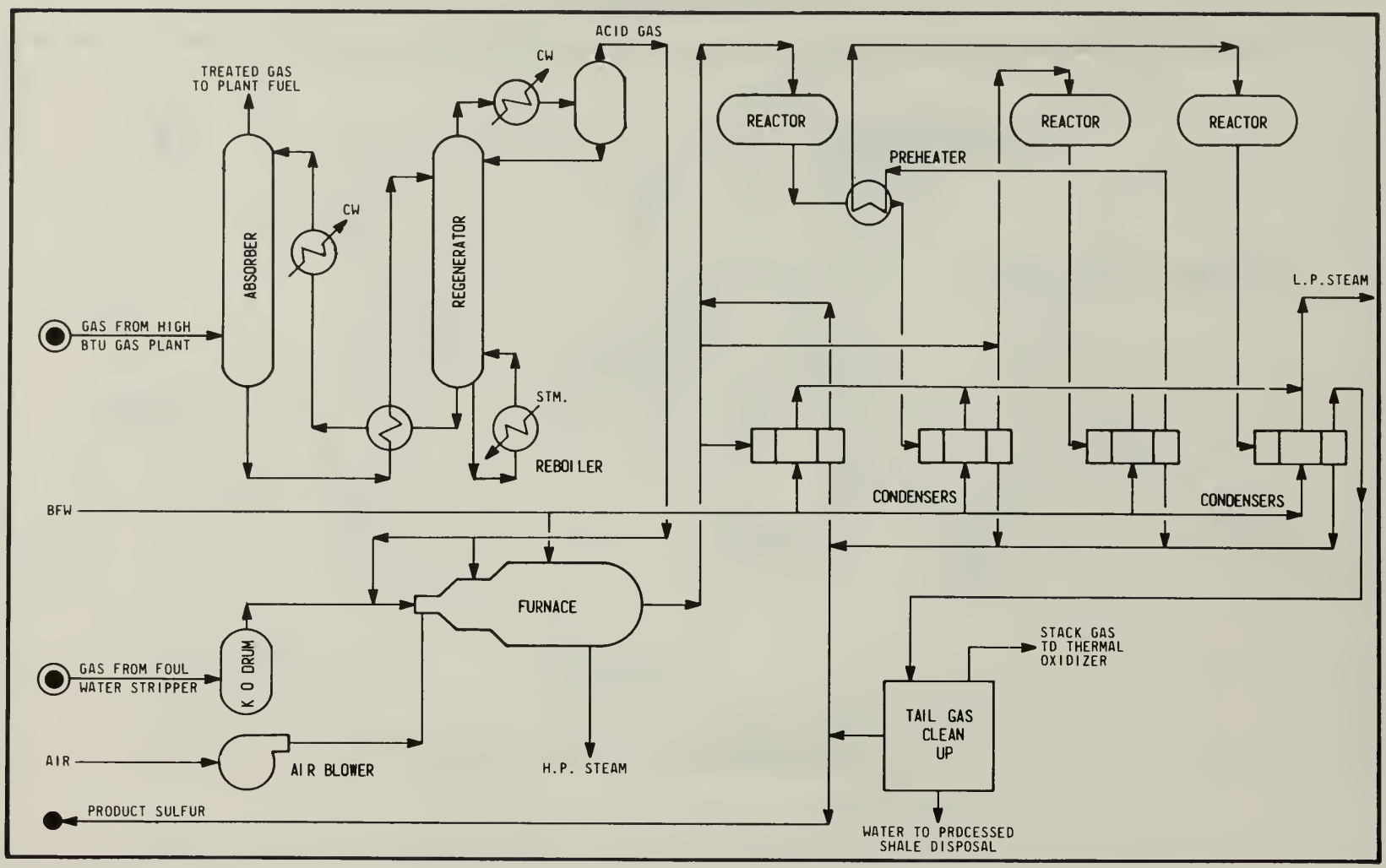


Figure 3-3-10
FLOW DIAGRAM OF SULFUR RECOVERY PLANT

licensed by the Shell Development Company. The purified gas, containing less than 100 ppmv total sulfur, is used as fuel in the processing facility. An acid gas containing the absorbed sulfur compounds is produced during regeneration of the Sulfinol solvent. This gas, together with the offgas from steam stripping of foul water, is fed to a Claus unit where sulfur compounds are converted to elemental sulfur. Most of the ammonia in the acid gas is converted to nitrogen, thereby minimizing emission of nitrogen oxides to the atmosphere.

Offgas from the Claus unit is further processed in a tail gas cleanup unit. Traces of sulfur compounds in the Claus unit tail gas are catalytically hydrogenated to hydrogen sulfide which is then converted to elemental sulfur. The clean tail gas, containing less than 250 ppmv of total sulfur, is incinerated in the thermal oxidizer. Elemental sulfur in molten form is sent to storage prior to shipment from Tract C-a.

e. Oil Upgrading and Blending Plant - This plant includes equipment necessary for blending various shale oil fractions to produce a pipelineable oil product. Raw naphtha produced in the oil fractionation plant, raw oil recovery plant, and high BTU gas plant is held in a floating roof storage tank from which it is pumped to a blending header. Heavy oil streams from the oil fractionation and raw oil recovery plants are combined and treated with chemical additives as required for pour point adjustment. The treated heavy oil passes through an in-line mixer to provide a homogeneous stream and is then stored in a cone roof tank. The C_4 fraction from the high BTU gas plant is held in pressurized storage tanks from which it is pumped to the product blending header.

Product oil is produced by blending the C_4 fraction, raw naphtha, and treated heavy oil. The blended oil product is pumped through a heater/cooler for final temperature adjustment prior to entering the product pipeline.

E. MIS Product Gas Utilization

1. Basis of Utilization - MIS retorting of oil shale produces a gas having a heating value of about 100 BTU/SCF, LHV, dry basis. This low BTU gas, including condensable hydrocarbons, has an energy content equivalent to about 25% of the energy content of raw oil shale. This represents a signficant by-product of the Commercial Phase retorting operation. Recovery of the heat energy of this gas was considered to be essential in commercial operation in order to utilize efficiently the oil shale resource on Tract C-a.

As described in Chapter 5 of this Section, several methods of utilizing the low BTU gas were considered. The method selected for the concept of the Commercial Phase operation involves purification of the gas to remove sulfur compounds followed by combustion of the purified gas in gas turbines to produce electric power. The power is used to supply most of the requirements of the processing facility.

2. MIS Retort Gas Purification Plant - A flow diagram of the purification plant is shown in Figure 3-3-11. Gas from the scrubber of the oil-gas recovery plant is compressed in multistage compressors equipped with inter and after coolers and separators. Oil and water separated out in the separators are sent to oil blending and foul water stripping plants, respectively. A small amount of the gas is sent to the TOSCO II retorting plant for use as fuel.

Compressed gas is contacted with an alkaline solution to convert carbonyl sulfide contained in the gas to hydrogen sulfide. The gas then flows to a Stretford type desulfurization system where hydrogen sulfide is absorbed from the gas and converted to elemental sulfur. The purified gas, containing about 50 ppmv of total sulfur, is sent to the power generation plant.

3. Power Generation Plant - A flow diagram of the electric power generation plant is shown in Figure 3-3-12. Purified fuel gas is burned with compressed air in the combustor section of the gas turbines. Hot

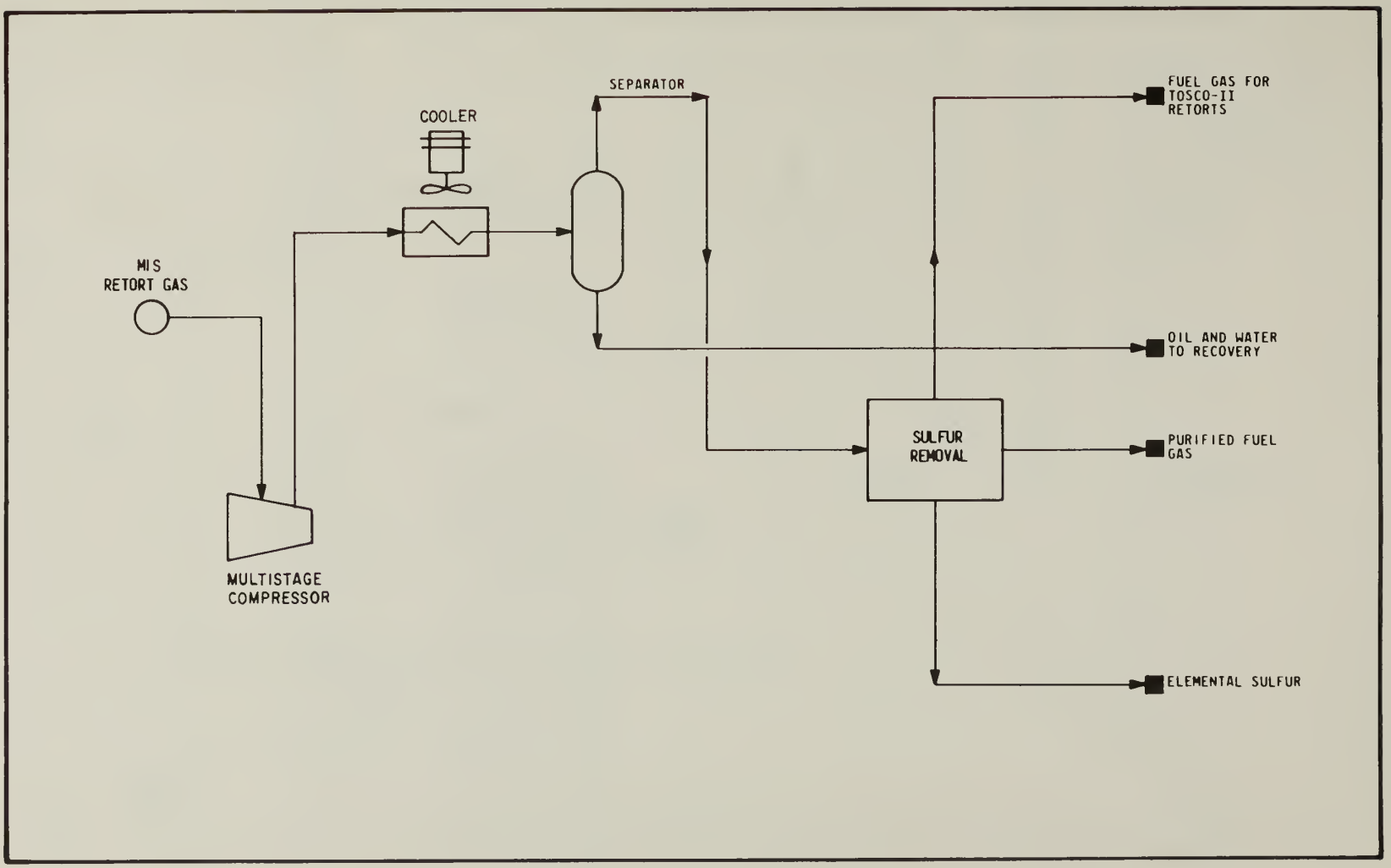


Figure 3-3-11
FLOW DIAGRAM OF MIS GAS PURIFICATION PLANT

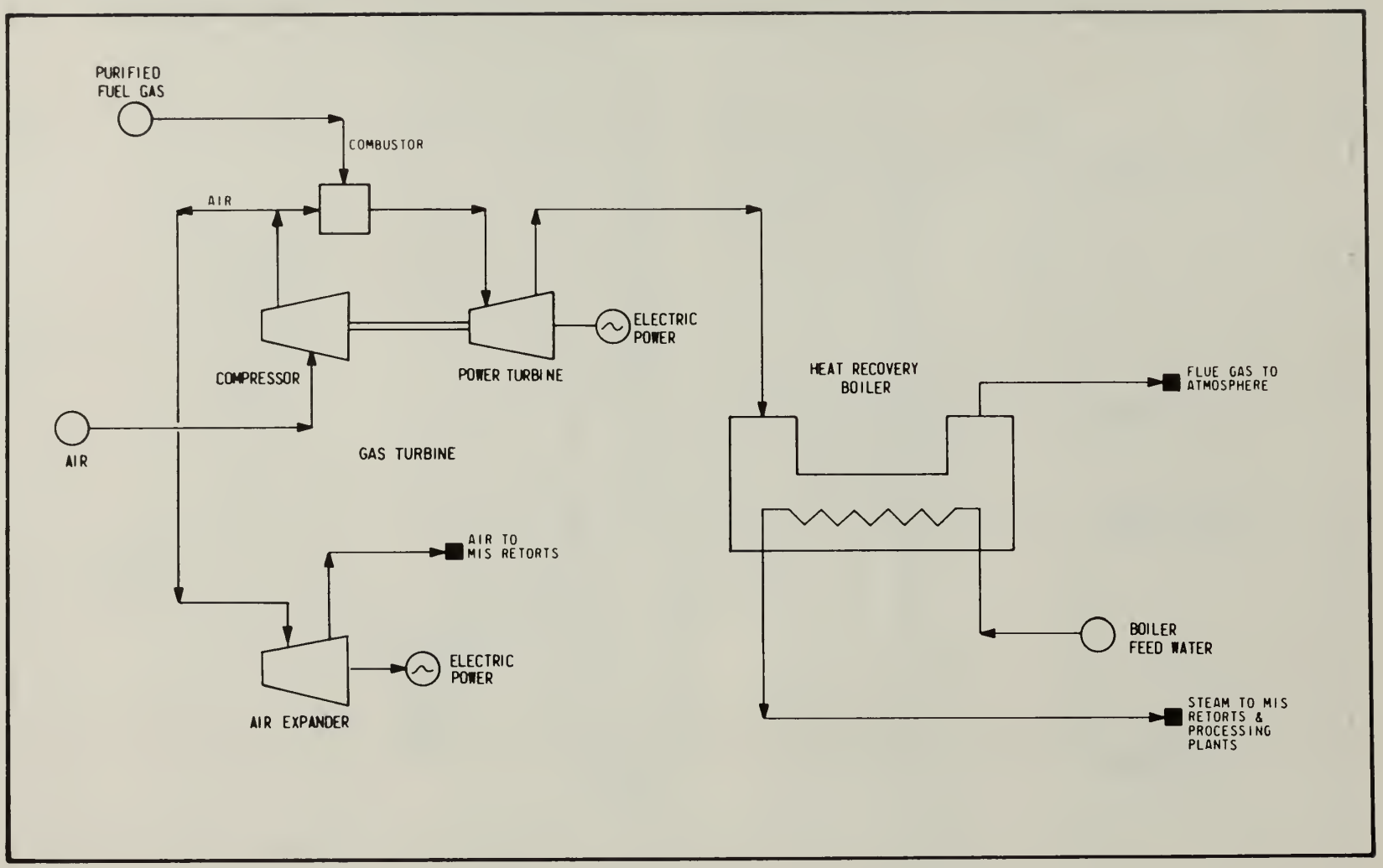


Figure 3-3-12
FLOW DIAGRAM OF POWER GENERATION PLANT

flue gas is expanded through the power turbines which drive electric generators. A portion of the combustion air compressed by the gas turbines is expanded to produce additional electric power and then sent to the MIS retorts.

Flue gas from the gas turbine is sent to heat recovery boilers to produce steam required by the MIS retorts and processing plants. Exhaust from the boilers is released to the atmosphere through elevated stacks.

F. Support Systems - These systems include:

- Water treatment
- Steam distribution
- Cooling water
- Oily water treatment
- Plant/instrument air
- Emergency electric power
- Fire water
- Thermal oxidizer and flare

1. Water Treatment - Raw water is needed in the processing facility to supply processing, cooling tower, steam generation and for miscellaneous uses. The system used to prepare feedwater for process steam generators and heat recovery boilers includes lime treatment system, filters, and ion exchange system.

2. Steam Generation - Systems are provided for high and low pressure steam requirements. A high pressure saturated steam boiler is provided for start-up purposes.

3. Cooling Water - Cooling water systems illustrated in Figure 3-3-13 are provided to supply cooling water to the processing plants. Cooling water quality is monitored and controlled by an automatic chemical system. Blowdown water from boilers and cooling tower is used ultimately to moisturize processed shale.

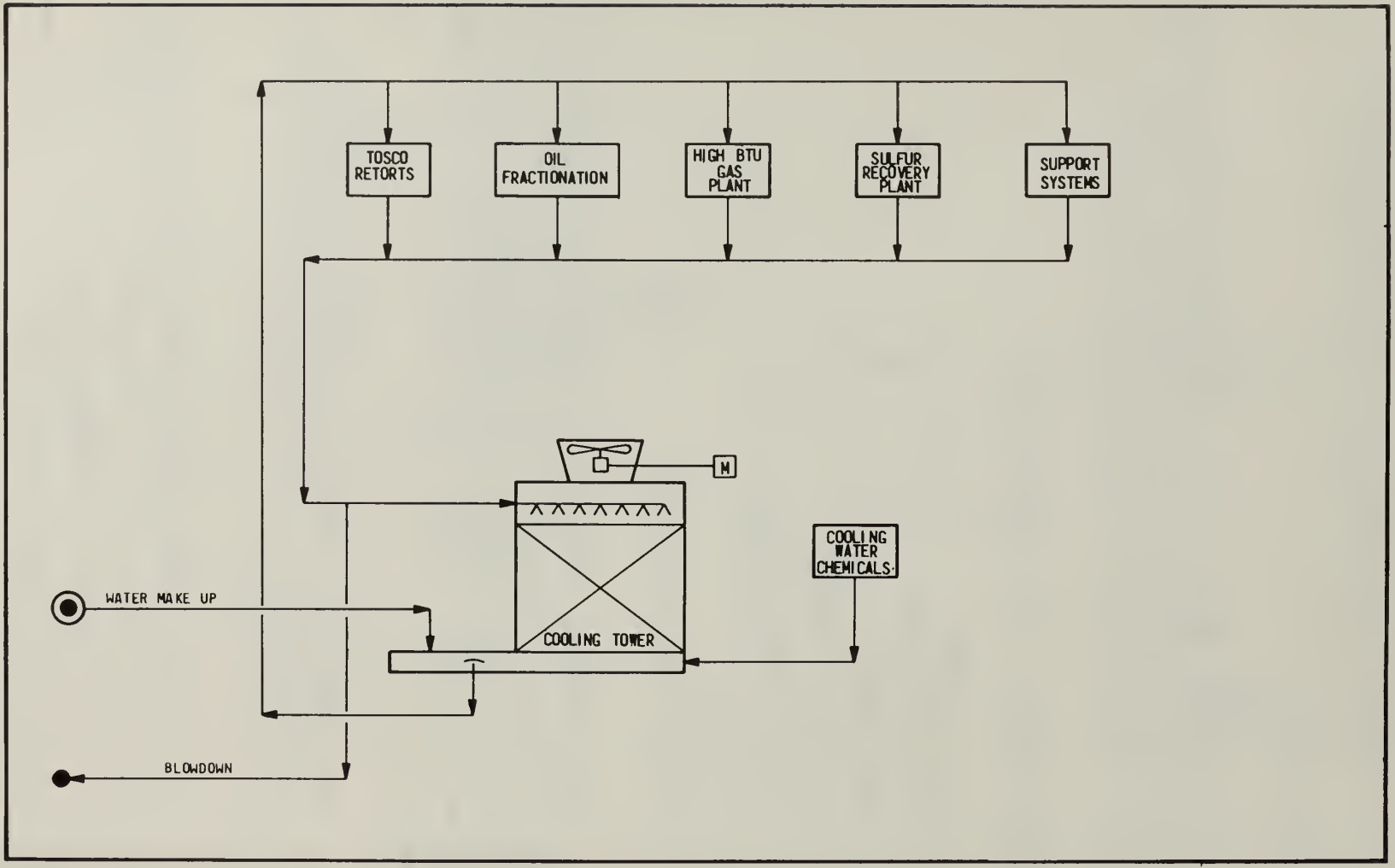


Figure 3-3-13

FLOW DIAGRAM OF SUPPORT SYSTEMS - COOLING WATER

4. Water Chemicals - Storage, handling and pumping systems are provided for conventional chemicals used in softening water and for boiler and cooling tower water quality control.

5. Oily Water Treatment - Any oily water washed from processing plant pads or from accidental leaks are sent through an oily water sewer to an API separator system. Separated oil is returned to the raw oil recovery plant and any sludge collected is removed periodically and burned in the thermal oxidizer. Effluent water from the API separator flows to a retention pond.

6. Plant/Instrument Air - A plant and instrument air system is provided to supply compressed air to the processing facility. Air is compressed, cooled, and stored in a receiver. Part of the air is dried and filtered for instrument air use.

7. Emergency Electric Power - The processing facility is supplied with electricity from the power generation plant. An emergency generator is provided, however, to insure electricity for essential plant systems in the event of loss of normal electric power supply. This ensures orderly shutdown of the equipment in case of power interruption.

8. Fire Water - The fire water system provided for the processing facility is connected to the overall project fire water distribution system. Details are discussed in Section 6, Chapter 3, Fire Prevention and Control.

9. Thermal Oxidizer and Flare - A thermal oxidizer system is included in the support systems to handle disposal of minor oil or gas waste products which cannot practically be recycled to the process. Sludge removed from the API separator, and tail gas from the sulfur recovery plant are sent to the thermal oxidizer. In addition, a part of the oil-containing solids separated from the TOSCO oil residue during centrifuging may also be sent to the thermal oxidizer if operating experience shows that this material cannot be recycled completely to the TOSCO II retort. At the present time, it is expected that all of the

oil-containing solids from the centrifuge will be recycled to the retort. A flare system will be used to dispose of liquids or gases that are unavoidably in excess during plant start-up, shutdown, or emergency conditions. These materials are thus burned before emission to the atmosphere during these circumstances.

G. Overall Material Balance - The Commercial Phase processing facility is designed to retort 170,000 TPSD of oil shale (dry basis) having an average Fischer Assay of 23 gallons per ton. The primary product of the operation is pipeline quality oil produced at a rate of 76,000 BPSD. By-product of the operation is elemental sulfur. The overall material balance for the operation is summarized in Table 3-3-2.

Table 3-3-2

COMMERCIAL PHASE OVERALL MATERIAL BALANCE

Oil Shale	
Retorting Rate, TPSD, dry basis	170,000
Fischer Assay, GPT	23
Pipeline Quality Oil Product	
Production Rate, BPSD	76,000
Properties	
^{o}API	26
True Vapor Pressure, psia	11.2 (@ 100^{o}F)
Viscosity, SSU @ 30^{o}F	800 max
Pour Point, ^{o}F	30 max
Sulfur By-Product	
Production Rate, LTPSD	265
Moisturized Processed Shale	
Production Rate, TPSD	36,000

H. Utility Requirements

1. Electric Power - The estimated rate of electric power production and consumption is summarized in Table 3-3-3. The power generation plant provides most of the power requirements of the processing facility.

Table 3-3-3

COMMERCIAL PHASE PROCESSING FACILITY
ESTIMATED ELECTRIC POWER BALANCE

Plant	Electric Power, MWH/H Consumed	Produced
MIS Retorting		
Retorting	4	-
Oil-Gas Recovery	7	-
Oil Fractionation	5	-
Gas Purification	200	-
Power Generation		226
Surface Retorting		
TOSCO II	30	-
Raw Oil Recovery	1	-
High BTU Gas Plant	7	-
Sulfur Recovery	1	-
Product Oil Blending	1	-
Foul Water Stripping	1	-
Support Systems	5	-
Purchased Power	-	36
Total	262	262

2. Fuel Balance - An estimated fuel balance for the Commercial Phase processing facility is shown in Table 3-3-4.

Table 3-3-4

COMMERCIAL PHASE PROCESSING FACILITY
ESTIMATED FUEL BALANCE

Plant	MM BTU/H (LHV) Produced	Consumed
a) High BTU Fuel Gas		
TOSCO II Retorting Plant	-	819
High BTU Gas Plant	-	27
Sulfur Recovery Plant	882	9
Support Systems	-	27
	882	882
b) Low BTU Fuel Gas		
MIS Gas Purification Plant	3,260	-
TOSCO II Retorting Plant	-	171
Power Generation Plant	-	3,089
	3,260	3,260
Total Fuel Gas	4,142	4,142

3. Cooling Water - Retorting and oil upgrading plants in the processing facility require cooling water to absorb heat which cannot be recovered for use in the complex or absorbed by air fan coolers. Cooling water is circulated through a wet cooling tower to reject this heat to the atmosphere. A summary of cooling water usage is given in Table 3-3-5.

Table 3-3-5

COMMERCIAL PHASE PROCESSING FACILITY
ESTIMATED COOLING WATER CIRCUATION

Plant	Cooling Water Circulation, gpm
TOSCO II Retorting Plant	1,300
Oil Fractionation Plant	3,800
Oil Blending Plant	100
High BTU Gas Plant	4,400
Foul Water Stripping Plant	600
Sulfur Recovery Plant	200
Support Systems	400
	10,800

4. Water Balance - The following summary describes the disposition of water involved in the normal operation of the Commercial Phase processing facility:

Output	gpm
Water on Processed Shale	840
Surface Retort Vent Gas Loss	840
Cooling Tower Loss	330
Power Generation Plant Flue Gas Loss	610
Miscellaneous Loss	130
Total Output	2,750
Input	
Raw Water Intake	820
Water of Combustion	530
Retort Water and Residual Groundwater Inflow	1,400
Total Input	2,750

Approximately 30% of the total water input is consumed in moisturizing processed shale from surface retorting. Evaporation and flue gas losses use essentially all of the remaining water input.

3.2 COMMERCIAL PHASE PROCESSING EMISSIONS AND CONTROL

This part of the Detailed Development Plan identifies sources of emissions from the Commercial Phase processing facility and describes pollution control techniques applied to these emissions.

A. Atmospheric Emissions - This section identifies atmospheric emission sources from the Commercial Phase processing facility, describes pollution control techniques applied to these sources and estimates emission rates after control. The location of the processing plants and stacks are shown in Figure 3-4-1. Estimates of emissions from the stacks are given in Table 3-3-6. Additional information on air quality control is discussed in Section 6, Chapter 5.

1. Fuel Source - Fuel required for the processing facility is supplied by purified high BTU gas and low BTU gas produced by retorting operations. Low sulfur fuel oil will be used to start up the processing facility.

2. Retorting

a. MIS Retorting - There will be no emissions from a Modified In Situ retort itself, which is a closed system without openings to the atmosphere.

b. TOSCO II Retorting - The TOSCO II retorting plant includes three modules, each containing shale preheating, ball heating and circulation, retorting, and processed shale conditioning systems. The sources of atmospheric emissions in this plant are described below.

1) Raw Shale Preheat System Stack - Hot flue gas from the ball heater and the incinerator is used to preheat raw shale and is then scrubbed in a wet scrubber prior to release to the atmosphere through an elevated stack. The ball heater is fired with desulfurized fuel gas while the incinerator is fired with a mixture of desulfurized

Table 3-3-6

COMMERCIAL PHASE PROCESSING FACILITY
ESTIMATED STACK EMISSION DATA

Stack Description	Preheat System	Steam Superheater-Ball Circ.	Shale Moisturizing	High BTU Gas Plant Reboiler	Thermal Oxidizer	Power Generation Plant
Stack Location No.	1	2	3	4	5	6
No. of Stacks	3	3	3	1	1	2
Stack Height, ft.(1)	330	330	330	150	150	330
Stack Diameter, ft.	12.0	6.0	3.0	3	9.5	35
Stack Gas Parameters						
Gas Flow						
LB/HR	1,815,000	384,000	212,000	20,700	280,000	10,000,000
ACFM	603,000	156,000	111,300	13,800	128,000	4,450,000
Molecular Weight	27.7	25.6	19.9	28.2	22.	30.5
Exit Temperature, ^{o}F	122	200	200	730	180	400
Moisture Content, Vol%	16	31	83	14	66	5
SO_2 Content						
LB/HR	42	0.6	-	0.3	31	384
PPM (Vol)	10	2.3	-	3	38	18
LB/MMBTU fired	0.046	0.015	-	.007	1.1	0.12
NO_x Content						
LB/HR	429	21	-	8	50	1,860
PPM (Vol)	143	30	-	225	85	123
LB/MMBTU fired	0.47	0.54	-	0.35	1.9	0.57
Particulates						
LB/HR	120	21	10	0.3	0.7	320
Grains/ACF	0.023	0.016	0.031	0.003	.006	0.1
Hydrocarbons						
LB/HR	147	-	-	0.6	0.7	20
Firing Duty, MMBTU/HR	307	13	-	22	27	3,260

(1) Measured from grade at TOSCO Retorting Plant.

Note: Carbon monoxide content of stack gases is negligible.

high BTU fuel gas and low BTU fuel gas. Sulfur compounds contained in these fuels form sulfur dioxide when burned in the ball heater combustion chamber and in the incinerator. Caustic is injected into the preheat system wet scrubber in order to remove sulfur dioxide from the flue gas down to an expected concentration of 10 ppmv.

Some nitrogen oxides are formed during combustion, primarily as a result of thermal reaction between molecular oxygen and nitrogen, commonly referred to as thermal NO_x. The ball heater and incinerator, however, are fired at relatively low flame temperature for process reasons and this tends to reduce thermal NO_x formation. In addition, the flue gas picks up shale dust and hydrocarbons as it passes through the shale preheat system in direct contact with raw shale. The incinerator is designed to reduce the hydrocarbon content of the flue gas while entrained shale dust is removed by the wet scrubber. Wet scrubbing of the flue gases causes the raw shale preheat system stack to emit water vapor as a visible plume under certain atmospheric conditions. Estimates of emissions from this stack are given in Table 3-3-6.

The wet scrubbers produce a slurry of raw shale dust and water which is sent to a clarifier where excess water is separated and recycled to the scrubbers. Thickened sludge from the clarifier is sent to processed shale disposal.

2) Steam Superheater - Ball Circulation System Stack - Each TOSCO II retort module contains a steam superheater fired with purified high BTU gas. Hot flue gas from the superheater is used to remove residual processed shale dust from the ball circulation system. Small quantities of processed shale dust from vents on the ball heater are combined with the dusty flue gas from the ball circulation system. Cyclones and a high energy venturi wet scrubber are used to remove shale dust from the combined flue gas before it is vented. The stack also emits a visible steam plume under certain atmospheric conditions. Estimates of emissions from this stack are given in Table 3-3-6.

Shale dust-water slurry from the wet scrubber is clarified and the sludge is sent to processed shale disposal.

3) Processed Shale Moisturizing System Stack - Steam generated in the process of cooling and moisturizing processed shale is sent to a high energy venturi scrubber where entrained shale dust is removed. The processed shale moisturizing stack emits water vapor as a visible plume and some residual shale dust. Estimates of emissions from this stack are given in Table 3-3-6.

Shale dust-water from the scrubbers is clarified and the sludge is sent to processed shale disposal.

3. Product Recovery

a. MIS Products

1) Oil-Gas Recovery Plant - Oil and gas produced by MIS retorting are separated in a closed system. There are no emissions to the atmosphere from this system.

2) Oil Fractionation Plant - Separation of MIS oil into naphtha and heavy oil fractions is also carried out in a closed system with no emissions of atmospheric contaminants. Heat for the separation is supplied by steam which is condensed in heat exchange equipment and returned to the steam condensate system.

3) Gas Purification Plant - This plant is a major emission control process for the Commercial Phase processing facility. Gas from the MIS retorts is processed in a closed system comprising compression and separation of condensed hydrocarbons and water, desulfurization of the compressed gas, and conversion of hydrogen sulfide to elemental sulfur. The purified gas, containing about 50 ppmv of total sulfur, is sent to the power generation plant. Tail gases from the desulfurization system are sent to the thermal oxidizer.

4) Power Generation Plant - The power generation plant utilizes purified gas produced by MIS retorting as fuel to produce electric power for use on Tract C-a. Flue gas from gas turbine power generators is discharged to the atmosphere after passing through a heat recovery system to generate steam. Estimates of emissions from this source are given in Table 3-3-6.

b. TOSCO II Retorting Products

1) Raw Oil Recovery Plant - There are no emissions of atmospheric contaminants directly from this plant. Oil vapors are condensed and fractionated in a closed system.

2) High BTU Gas Plant - This plant separates vapors from the raw oil recovery plant into a C_3 and lighter fuel gas, a liquid C_4 fraction, and a liquid C_5 plus fraction. Heat required for the separations is supplied by combustion of purified high BTU gas in a fired reboiler. Estimates of emissions from this source are given in Table 3-3-6.

3) Foul Water Stripping Plant - The foul water stripping plant removes hydrogen sulfide and ammonia from foul water streams recovered in the processing operations. This system is a major atmospheric emission control process since it removes these contaminants from water which is ultimately used for moisturizing processed shale. Gas from the stripper is sent to the sulfur recovery plant where hydrogen sulfide is converted to elemental sulfur. Stripped water is reduced in volume by evaporation in a closed system. Distillate water is recycled to the water treatment plant while residual water is used to moisturize processed shale. Heat for stripping and evaporation is supplied by steam which is condensed in heat exchange equipment and returned to the steam condensate system.

4) Sulfur Recovery Plant - The sulfur recovery plant is one of the major emission control processes used in the Commercial Phase processing facility. Gas from the high BTU gas plant is contacted with Sulfinol solution in an absorber tower in order to remove sulfur compounds. Purified gas from the absorber is used as fuel for the processing facility. Sour off-gas and gas from the foul water stripper are sent to the Claus Unit for conversion of sulfur compounds to elemental sulfur. Most of the ammonia in the gas is converted to nitrogen thereby minimizing the emission of nitrogen oxides to the atmosphere. Off-gas from the Claus unit is processed in a tail gas cleanup unit for conversion of residual sulfur compounds to elemental sulfur. Tail gas from the unit is incinerated in the thermal oxidizer.

5) Oil Upgrading and Blending Plant - Treatment of oil fractions with flow-improving additives and blending of oil to produce the pipeline quality oil product is carried out in closed vessels.

4. Support Systems - The thermal oxidizer is the principal source of atmospheric emission in the support systems. During normal operation of the processing facility, sludge from the API separator and tail gases from desulfurization systems will be incinerated, and the flue gas discharged to the atmosphere. Estimates of emissions are given in Table 3-3-6.

Tankage for storage of intermediate and final oil products is required for proper operation of the processing facility. Vapor losses from storage tanks are controlled by using a floating roof tank for the more volatile oil. Descriptions of the storage tanks and estimates of tank vapor losses are given in Table 3-3-7.

B. Disposal of Solid Waste Other Than Processed Shale - In addition to processed shale, a number of other solid wastes are produced by the processing facility. These can be summarized as follows:

Table 3-3-7

COMMERCIAL PHASE PROCESSING FACILITY
ESTIMATED TANK VAPOR LOSSES

Tank Description	MIS Oil Storage	Naphtha Storage	Heavy Oil Storage	Gas Oil Storage	Fuel Oil Storage	Fuel Oil Day Tank
Tank Service	Raw Oil	Naphtha	Heavy Oil	Gas Oil	Fuel Oil	Fuel Oil
Tank Data						
Number	1	1	2	1	1	1
Dimensions, ft	80Ø x 56	90Ø x 64	120Ø x 60	18Ø x 24	50Ø x 60	18Ø x 24
Capacity, BBL each	50,000	70,000	120,000	1,000	20,000	1,000
Type	Cone Roof	Floating Roof	Cone Roof	Cone Roof	Cone Roof	Cone Roof
Storage Temp ^{o}F	55	55	200	55	55	55
Avg. Outage, %	50	50	50	50	50	50
Annual Turnovers	365	18	73	1	18	365
Vapor Pressure of Contents, psia	0.01	2.2	0.01	0.01	0.02	0.02
Tank Vapor Losses, BBL/Yr						
Each	65	67	11	7	11	2
Total	65	67	22	7	11	2

- Spent water treatment ion exchange materials and lime sludge.
- Deactivated sulfur recovery catalysts.

Catalysts used in the sulfur recovery plant gradually lose effectiveness and must be replaced to maintain conversion efficiency of the process. Deactivated catalysts will be returned to catalyst manufacturers or other firms interested in reprocessing these materials. Lime sludge and spent water treatment ion-exchange materials will be disposed of with the processed shale. The maximum quantity of solid wastes that requires disposal represents only about .007% of the processed shale produced annually. The type and estimated quantity of solid wastes requiring disposal are shown in Table 3-3-8. The expected disposal method is discussed in Section 6, Chapter 9.

C. Processing Water - The Commercial Phase processing facility is designed to avoid discharge of waste processing water into the environment. Water removed from the processing plants and support systems will be used to moisturize processed shale and as makeup to wet scrubbing systems. Water quality is discussed in Section 6, Chapter 6.

Table 3-3-8

COMMERCIAL PHASE PROCESSING FACILITY SOLID WASTES

Processing Plant	Solid Waste Description	Approximate Quantity
Sulfur Recovery		
Claus Unit	Spent oxidation catalyst	45 TPY*
Tail Gas Unit	Spent hydrogenation catalyst	8 TPY*
Support Systems		
Water Treating	Spent zeolite	3 TPY
Water Treating	Lime sludge	870 TPY

*Averaged over catalyst life.

CHAPTER 4
PLOT PLAN

4.1 PARAMETERS

The Modular Development Phase (MDP) and Commercial Phase processing facilities are located entirely within the boundaries of Tract C-a. A plot plan for the processing plants and support systems was developed by considering the following key parameters:

- Location of the processing facilities to minimize distances from the MIS retorts and the disposal area for surface-processed shale.
- Selection of elevated topography to enhance dispersion of stack emissions.
- Selection of relatively level terrain to minimize site preparation and terracing.
- Location of processing facilities so that the MDP can be expanded to commercial operation with minimum interference with existing facilities.
- Orientation of individual processing plants to minimize interplant transfer distances for oil and gas.
- Location of processing facilities for ease of access to corridors and product shipment systems.

4.2 MODULAR DEVELOPMENT AND COMMERCIAL PHASE PROCESSING FACILITIES

A plot plan depicting the arrangement of facilities for processing operations is shown in Figure 3-4-1. Product gas compressors for commercial MIS retorting operations are located on the MIS mine shaft pillar near the center of Tract C-a. This location also serves as the collection point for MIS retorting product gas.

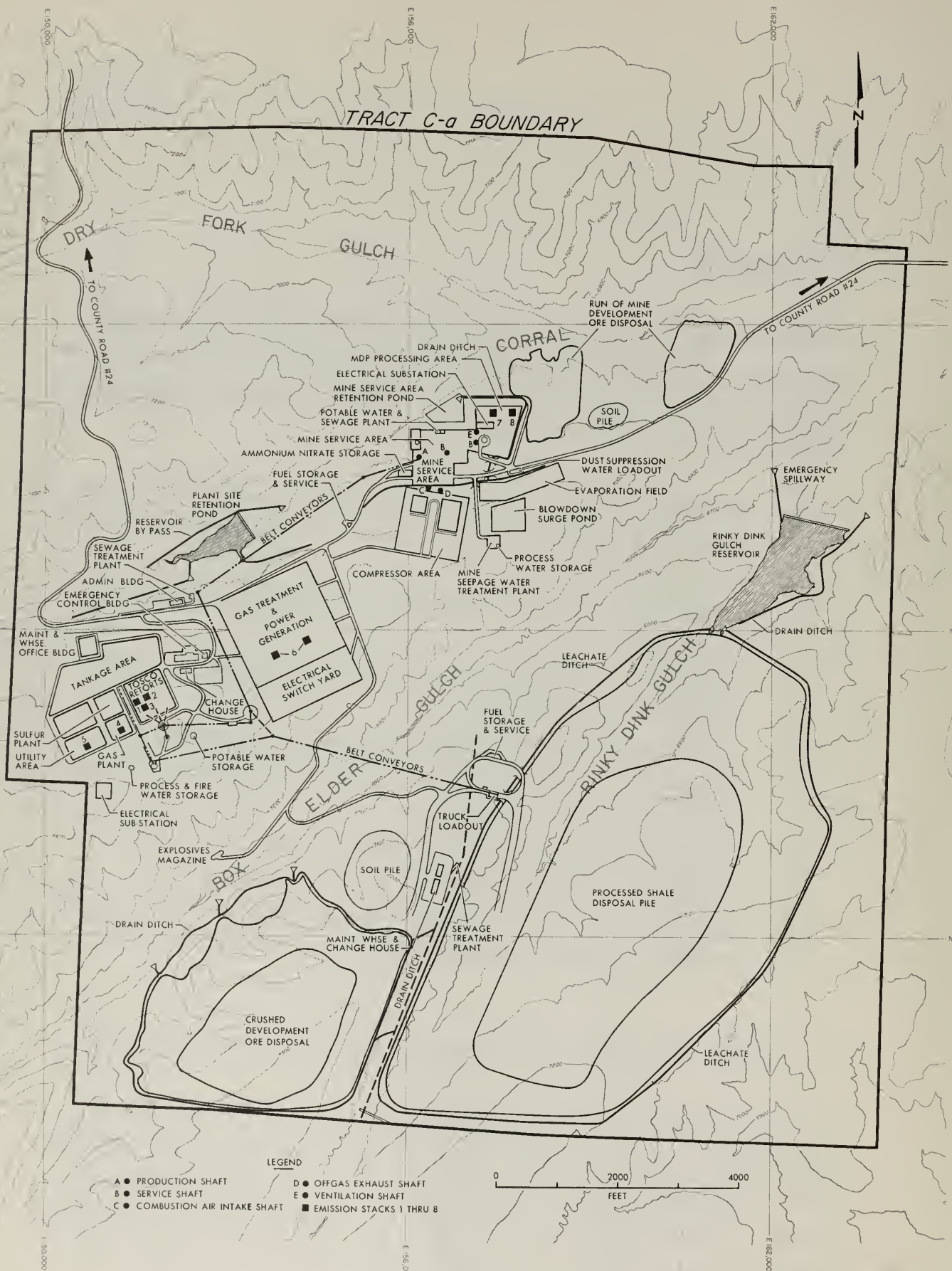


Figure 3-4-1

PLOT PLAN

The processing facility is located on Airplane Ridge. The MIS gas purification and power generation plants are located as close as practicable to the mine shaft pillar area in order to minimize transporting large volumes of air and MIS gas. The TOSCO retorting plant, and associated processing plants, support systems, and tankage are located to the southwest of the power generation plant. Disposal of surface-processed shale will be in the southeast quadrant of Tract C-a.

The MDP involves operation of a series of MIS retorts of progressively larger size, culminating in the demonstration of a commercial size MIS retort. These retorts will be located on the eastern side of the shaft pillar. The processing facilities for this operation are located in the same area to minimize transport distances for retort products to collection systems and the thermal oxidizer, and to avoid interference with the planned commercial processing facility.

The plot plan shown in Figure 3-4-1 dipicts the present concept for the layout of MDP and Commercial Phase processing facilities. This plan is preliminary and may change as detailed engineering proceeds. It is expected that these changes will not alter the basic concept presented at this time.

4.3 STACK LOCATIONS

Atmospheric emission points in the Modular Development Phase and Commercial Phase processing facilities are indicated on the plot plan. Each stack is identified with a number which is referenced on Tables 3-2-1 and 3-3-6 that list estimates of atmospheric emissions.

CHAPTER 5

COMMERCIAL PHASE PROCESSING ALTERNATES

5.1 RETORTING

A. Background - Production of oil from oil shale requires heating the shale to a temperature of about 900° F. Under these conditions, endothermic chemical reactions convert kerogen to oil, gas and residual carbon. This thermal treatment, known as retorting, can in principle be carried out in situ or aboveground. In evaluating retorting methods for use on Tract C-a, criteria were applied that requires the process be:

- Capable of continuous operation at high throughput in a large scale shale oil facility.
- Capable of efficient production of oil from shale.
- Based on demonstrated technology available to RBOSP.

B. In Situ Retorting - Oil shale in its natural state in the ground is relatively impermeable to fluids except for some naturally occuring joints and interconnected vugs. Therefore, it is necessary to create permeability, typically by fracturing the shale deposit, in order to practice in situ retorting effectively. In general, the techniques employed are classified as true in situ or modified in situ retorting. In the former, a permeable zone is created, for example, by steam flooding, hydraulic fracturing, or fracturing with explosives. An oxygen-containing gas is injected into the zone and a combustion front is established which moves through the oil shale. Combustion of a portion of the shale provides the heat required for retorting. The Laramie Energy Research Center of ERDA has conducted field tests of true in situ retorting using explosive and hydraulic fracturing to establish communication between injection and production wells. Results of the Laramie tests have been encouraging in that a combustion zone was established and moved through the oil shale so that oil was produced.

In the Modified In Situ procedure, a portion of the oil shale is removed from the ground by mining. A permeable zone is then created by exploding adjacent shale and producing a rubble suitable for retorting. A combustion front is moved through the rubblized shale, driving oil and gas products of retorting to a recovery area. Occidental Research Corporation has published information on field tests of its in situ retorting process. Occidental has tested the retorting of several relatively small retorts prepared by their Modified In Situ method and reported oil yields exceeding 60 percent of the Fischer assay of the retorted shale.

Lawrence Livermore Laboratories is developing, under ERDA sponsorship, another Modified In Situ retorting process. In the RISE (Rubble In Situ Extraction) process, shale rubble is created by a mining process using a modified sublevel caving technique. Approximately 20% of the rubblized shale is removed to the surface. This mining technique is capable of preparing uniform rubble on a large scale and permits continual measurement of rubble size so that adjustment of explosives can be made. Retorting of the rubblized shale is carried out continuously from section to section as the mining proceeds.

After a review of in situ retorting technology, RBOSP selected the Modified In Situ (MIS) retorting process for application to Tract C-a. This process has the potential of achieving high oil yield and can be adapted to the retorting of thick oil shale deposits on a large commercial scale.

C. Aboveground Retorting

1. Retorting Processes - The Bureau of Mines has classified aboveground retorts as follows:

Class	Method of Heat Transfer	Examples
I	Transfer through a wall	Pumpherston
II	Transfer from combustion in the retort	NTU, Gas Combustion, Paraho
III	Transfer from externally heated gases	Union Oil, Petrosix, Paraho
IV	Transfer from externally heated solids	TOSCO II, Lurgi

A review of these types of retorts was made to select those which would be suitable for retorting of shale brought to the surface during MIS mining.

The criteria for retort selection given previously eliminated Class I retorts from consideration since heat transfer through walls was not considered practical for large capacity operation. Among the Class II, III, and IV retorts, the NTU retort was eliminated since it is not a continuous flow retort. The Gas Combustion and Paraho retorts were eliminated on the grounds that these retorts, although suitable for use in combination with other types of surface retorts, produce low BTU gas which would be available in large quantity from the MIS retorting operation. The TOSCO II, Union Oil, and Lurgi retorting processes were judged to be suitable for use on Tract C-a in conjunction with MIS retorting. RBOSP purchased a license for the TOSCO II process and is continuing discussions with Union Oil and Lurgi concerning their processes. The TOSCO II process has been used in this Detailed Development Plan to illustrate the concept of a commercial shale oil facility. RBOSP is continuing to study alternatives for surface retorting and may modify the Detailed Development Plan to reflect future advances in technology.

2. Background of TOSCO II Process - Development of the TOSCO II process for oil shale retorting was started in 1956. Denver Research Institute carried out laboratory research for The Oil Shale Corporation. The first pilot plant was installed near Littleton, Colorado, in 1957

and, in 1964, a 1,000 TPD semi-works retort was installed on the Dow property in the Middle Fork Canyon of Parachute Creek in Colorado.

TOSCO operated the semi-works plant from 1965 to 1967 and again in 1971 and 1972 to improve the process and to prove out various aspects of commercial plant design, including various types of pollution control equipment. Tests on the TOSCO pilot plant were carried out specifically for RBOSP to obtain design data.

5.2 HIGH BTU GAS PURIFICATION

A. Considerations - The Commercial Phase operation on Tract C-a will involve surface retorting of the shale brought aboveground as a result of the MIS mining operation. Retorting of shale in a TOSCO II plant produces a significant quantity of high BTU gas which can be used as fuel for the processing facility. The raw gas, however, contains volatile sulfur compounds which form sulfur dioxide when the gas is burned. Various methods of desulfurizing the high BTU gas were considered in order to minimize atmospheric emissions from the processing facility.

B. Processes - A number of commercially demonstrated processes are available for desulfurization of high BTU gases. These processes typically involve absorption of the volatile sulfur compounds in a circulating solvent stream. Regeneration of the solvent leads either to a concentrated "acid gas" which is treated further to recover elemental sulfur, or to production of elemental sulfur directly.

All of the processes are capable of producing clean fuel gas and the final selection of the process for the Commercial Phase processing facility will be made when detailed engineering work is started. To illustrate the concept of the commercial facility, the Sulfinol process was selected for desulfurization of the high BTU gas. Acid gas from the Sulfinol plant is sent to a Claus sulfur recovery plant.

5.3 SULFUR RECOVERY

Another area where process alternates were considered for the Commercial Phase processing facility is the tail gas cleanup section of the sulfur recovery plant. The offgas from the last Claus converter is treated to increase the overall sulfur recovery from about 95% to 99+%. Commercial processes applicable to treating sulfur plant offgas include Beavon, Cleanair, Scot, and Wellman-Lord. The first two processes convert residual sulfur in the tail gas directly to elemental sulfur. Basically, these systems combine catalytic hydrogenation of sulfur compounds to form hydrogen sulfide with direct oxidation of hydrogen sulfide to sulfur in a Stretford unit. The Beavon process employs two reaction stages as compared to three for the Cleanair system. The Scot process hydrogenates all sulfur compounds in the tail gas to hydrogen sulfide which is then recovered by solvent absorption and recycled to the Claus unit.

Wellman-Lord first converts residual sulfur to SO_2 by oxidation and recovers SO_2 by alkaline absorption from the tail gas. The recovered sulfur dioxide is also recycled to the Claus plant for conversion to elemental sulfur.

These tail gas processes are essentially equivalent in terms of sulfur recovery and are all capable of producing a clean stack gas having less than about 200 ppm of sulfur as SO_2. The Beavon process was selected for the Commercial Phase processing facility although the other processes will be kept under consideration.

5.4 LOW BTU GAS UTILIZATION

Operation of the Commercial Phase MIS retorts will produce a significant quantity of by-product low BTU gas. The chemical energy contained in this gas could be used to provide power for processing equipment such as compressors, pumps and fans. Recovery of this chemical energy requires

combustion of the gas in suitable equipment. In principle, water-wall or refractory lined firebox steam boilers and gas turbines appear to be feasible systems for this application and could be considered for use in the Commercial Phase operation. Water-wall steam boilers have been operated successfully on low BTU blast furnace gas. Refractory lined waste heat boilers have been used extensively for combustion of waste gases from oil refinery operations. Gas turbines have also been operated successfully on blast furnace gas. In addition, gas turbine manufacturers are carrying out programs directed toward development of advanced gas turbines using low BTU gas fuels.

Final selection of a system for utilizing MIS retort gas in the Commercial Phase processing facility requires detailed evaluation of candidate systems. Since this evaluation will be carried out when final design of the Commercial Phase facility is started, it is not possible to identify at present the optimum system. The following approach was used, however, to make a preliminary selection for the Detailed Development Plan.

Steam boilers fired by MIS retort gas could be used to generate high pressure superheated steam for steam turbine drivers or for steam turbine-electric generator sets. These systems, however, involve substantial water consumption as a result of cooling tower evaporation and blowdown and boiler feed water treatment blowdown. Dry cooling systems can be used with steam power systems but result in a loss of efficiency and an increase in cost. Water usage is a matter of concern regarding the use of steam power systems for commercial operation on Tract C-a.

Gas turbines fired by MIS retort gas could be used to drive electric generators to supply power for the commercial facility. Open cycle gas turbine systems involve very little water consumption but are usually less efficient than steam boiler-steam turbine systems. Combined cycle gas turbine systems have higher efficiency than open cycle gas turbines but involve water consumption for the steam portion of the cycle. This water consumption is, however, substantially lower than that of steam power plants. In view of this more favorable situation, open cycle gas

turbines were selected for the present concept of the Commercial Phase processing facility.

Oxygen (generated from oxygen plants) could be used in place of air in order to produce a higher BTU gas but a cursory study indicated this route was not feasible due to high power requirements.

5.5 MIS GAS PURIFICATION

Gas produced from MIS retorting of oil shale contains hydrogen, carbon monoxide, light hydrocarbons, nitrogen (from combustion air), water vapor and carbon dioxide. The carbon dioxide results from combustion and from decomposition of mineral carbonates present in the raw oil shale. Water vapor results from combustion, retorting reactions, free moisture contained in the shale, and steam injected in the retorts. The composition of MIS retort gas with respect to major components is reasonably well established. There is considerable uncertainty at present, however, regarding the concentration of gaseous sulfur compounds since no in situ retorting operations have been carried out on Tract C-a shale. Present indications are that the sulfur content of the gas could range up to about 4000 ppmv and that the principal gaseous sulfur species is hydrogen sulfide. Significant amounts of other volatile sulfur compounds such as carbonyl sulfide and carbon disulfide, however, may also be present. In addition, the raw retort gas carries a significant amount of normally liquid hydrocarbons which have been vaporized from the shale oil product. These vaporized hydrocarbons have sulfur contents similar to those of raw shale oil.

In view of these uncertainties it is not possible at the present time to choose the best available purification method. Flue gas scrubbing with lime or limestone could be considered since all sulfur compounds in the retort gas would be present after combustion as sulfur dioxide which would be absorbed by the alkaline scrubbing solution. This method does not require detailed information on the type of sulfur compounds present

in the gas before combustion but has the disadvantage of consuming water as blowdown or vaporization from the scrubber.

Conventional gas scrubbing processes, including those using so-called chemical absorbents or physical absorbents, were also considered as means to remove sulfur compounds from the MIS retort gas before combustion. Processes using chemical absorbents, such as potassium carbonate solutions, are potential candidates for this application since these solutions absorb hydrogen sulfide at relatively low pressure, consistent with the pressure at which the gas is produced. Carbon dioxide is extensively absorbed in alkaline solutions, however, and this results in a significant energy penalty to regenerate the solution and leads to a problem of purifying the waste carbon dioxide gas. Processes using physical solvents must be operated at higher pressures to obtain efficient absorption of hydrogen sulfide. Compression of the retort gas represents an energy penalty but allows separation of at least a part of the sulfur-containing hydrocarbon vapors as a liquid condensate. Physical solvent gas scrubbing processes also tend to absorb significant amounts of carbon dioxide together with hydrogen sulfide. This situation increases the difficulty of recovering elemental sulfur from hydrogen sulfide diluted extensively with carbon dioxide.

Another method considered for purifying MIS retort gas involves the following steps:

- Compression of the gas followed by separation of the condensed hydrocarbon vapors.
- Hydrolysis of contained carbonyl sulfide.
- Desulfurization of the gas in a process equivalent to the Stretford process where hydrogen sulfide is absorbed and converted to elemental sulfur without extensive adsorption of carbon dioxide.

This method was adopted for the present concept of the Commercial Phase processing facility since it has the potential of providing a high

degree of desulfurization of the MIS retort gas and is compatible with the use of gas turbines for power generation, as discussed previously. Study of MIS gas purification methods will be continued, particularly in light of results obtained during the Modular Development Phase, in order to make a final selection of the system.

CHAPTER 6

MODULAR DEVELOPMENT PHASE ALTERNATES

The Modular Development Phase (MDP) processing facility is oriented toward demonstration of MIS retorts which are the principal means of retorting in the Commercial Phase. Evaluation of alternates for the MDP was therefore directed primarily toward treatment of the products from the retorting operations.

6.1 DISPOSAL OF MIS RETORTING GAS

Operations during the Modular Development Phase will be directed toward demonstration of the MIS retorting process. A series of retorts of progressively increasing size will be prepared and operated. The program will culminate in the operation of a commercial size retort to demonstrate the technical and economic feasibility of commercial operation. The retorts will be operated on a planned intermittent schedule in order to evaluate results of a completed retort and apply this experience to the next retort. As a result, the gas produced from the retorts will have little value as a reliable source of power for the processing facility.

Methods of disposing of the gas on the tract were considered since it is not feasible to transport the gas off-tract. Release of the gas directly to the atmosphere was rejected because of resulting undesirable atmospheric emissions. Incineration of the gas in a thermal oxidizer was considered the preferred procedure.

Purification of the gas, either prior to or following incineration was considered as a further means of controlling atmospheric emissions. Uncertainties concerning the type and concentration of gaseous sulfur compounds in the gas precluded selection of a purification process for the gas prior to incineration.

Scrubbing of the thermal oxidizer flue gas with an alkaline solution was considered a more reliable means of controlling atmospheric emissions. Flue gas scrubbing processes do not require detailed knowledge of the type of sulfur compounds in the gas prior to combustion and can be designed for a range of sulfur dioxide concentrations in the flue gas.

6.2 DISPOSAL OF MIS OIL PRODUCT

Production of oil from the MDP retorts will be relatively small and intermittent due to the schedule of retort operation. Shipment of the oil from the tract to a destination to be selected by Rio Blanco was considered preferable on environmental grounds to storing the oil on tract or to incinerating the oil.

6.3 DISPOSAL OF MIS WATER PRODUCT

Water produced from the MDP retorts will be a relatively small quantity and intermittent in flow. This water will be sent to the thermal oxidizer.

SECTION 4

PROCESSED SHALE & DEVELOPMENT ORE DISPOSAL

CHAPTER 1
INTRODUCTION

Disposal planning for processed shale is predicated on utilization of a disposal area located in Rinky Dink Gulch in the southeast quadrant of Tract C-a. This location was selected as the on-tract location most compatible with the MIS operation. Disposal activities are designed to coincide with the TOSCO II retorting production schedules. If processed shale is used to fill burned MIS retorts for possible subsidence control or abandonment mitigations, the amount of processed shale to be deposited in Rinky Dink Gulch will be reduced (see Section 6, Chapter 13.2, Subsidence Mitigation; and Section 6, Chapter 14-1, Abandonment). As final slopes are established on the disposal pile it will be progressively reclaimed. It is expected that within a few years after termination of processed shale disposal in Rinky Dink Gulch, the waste disposal area will have been contoured commensurate with surrounding topography and completely revegetated.

TOSCO II retorts are scheduled to be operational in early 1987. Each TOSCO II module is capable of retorting about 12,000 TPSD of oil shale.

Disposal of processed shale will begin when the TOSCO II retorts are operational. A relatively constant amount of processed shale will be generated throughout the life of the project. Therefore, the equipment, manpower and disposal requirements will also remain relatively constant.

Processed shale will be transported by an overland belt conveyor system approximately 6,500 feet to truck load-out facilities near the disposal area. Bottom-dump trucks (150-ton capacity) or large rubber-tired scrappers will haul and distribute the material on the disposal pile. Segmented foot compactors and haulage equipment will be used to compact the material.

Development ore disposal is divided into two phases: run of mine (ROM) and crushed. ROM ore, nominal size 24" and under, will be produced through year 1984 as underground mining for the Modular Development Phase progresses. This material will be moved by truck to the ROM disposal piles east of the mine service area. Crushed ore, 8" and under, will be produced from 1985 on as development mining for the Commercial Phase proceeds. This material will be moved by the conveyors that will be used in the Commercial Phase to move ore to the TOSCO II retort and processed shale to the disposal area. Trucks will load the ore from the loadout bins at the end of the conveyor system to the crushed development ore disposal pile in the southwest corner of the tract.

Chapter 2 of this section presents a description of the processed shale disposal operation including: design criteria; characteristics of disposal materials; site location and areal requirements; site preparation; processed shale conditioning, transport and placement; equipment selection structures and civil work; rehabilitation and water control.

Chapter 3 of this section presents a description of the development ore disposal operation.

CHAPTER 2
PROCESSED SHALE DISPOSAL OPERATION

2.1 DESIGN CRITERIA

Processed shale production from surface retorts is scheduled to begin in early 1987. Processed shale haulage and placement equipment scheduling must correspond to the production rates and schedules of the retorts to ensure reliability of the system. Production rates for equipment sizing were calculated using a moisture content of 15% (weight) and a design availability factor of 0.8. Processed shale will leave the retorts with up to 14% (weight) moisture. Additional watering to prevent dusting may raise this somewhat which would counter moisture loss through evaporation. Therefore, an estimated 15% moisture for processed shale is considered valid. Annual processed shale volumes were determined from annual dry processed shale tonnages (36,000 TPD) using an estimated compacted density of 85 pounds per cubic foot (pcf). Total compacted processed shale volume for the project is about 310 million cubic yards.

2.2 CHARACTERISTICS OF TOSCO II PROCESSED SHALE

The characteristics of TOSCO II processed shale have been determined by tests conducted by TOSCO and other Colony Development Operation participants. TOSCO II processed shale was found to be an extremely fine material with a variable dry bulk density of 55 to 65 pcf. Processed shale particles are crystalline and bulky as opposed to platy, with little variation in particle size. A typical particle size distribution, shown in Table 4-2-1, indicates that processed shale contains a very high percentage of fine material (39.6% less than 200 mesh).

RBOSP intends to completely cover the processed shale with coarse granular material (crushed development ore) and soil for revegetation

Table 4-2-1

TOSCO II PROCESSED SHALE
SIEVE ANALYSIS

Mesh Size	% Passing Dry Weight
4	95.3
10	88.2
20	82.6
40	78.8
80	61.0
100	55.2
200	39.6
325	31.0

(Section 6, Chapter 8, Land Rehabilitation). Prior to this, working or active slopes of processed shale will be exposed. The characteristics of TOSCO II processed shale will affect the behavior of the exposed slopes.

The stability of processed shale is inversely proportional to moisture content. The angle of repose for dry TOSCO II processed shale is about 35^{o}. However, under saturated conditions, the angle of internal friction is 20^{o}, slightly steeper than a 3:1 slope. If moisture content of the processed shale is less than that of saturation, the average angle of internal friction is 32^{o}, and the average cohesion is 1000 psf. Saturated cohesion for processed shale averages 400 psf.

Slope failure due to liquefaction is a critical factor which must be considered in the design of a processed shale disposal pile. The pile should be constructed so that the pile will not become saturated. The pile has been designed to a 4:1 slope so that, if the outer surface (say about two feet) of the processed shale pile were saturated and a 1.5 safety factor were included, the pile will remain stable at an infinite height. With a 4:1 slope, seismic effects on an outer saturated layer (shock-induced liquefaction) would only result in minor slumpages or bulges.

It is estimated that 5% settlement will occur in a pile approximately 1000 feet high. Field compaction tests, conducted at Colony Development Operation's test plot of processed shale in 18-inch lifts, indicate a moisture content of 13% will provide a maximum compacted density of 100 to 110 pcf. Experience with fine grained material on large earth projects indicates that a compacted density of at least 85 pcf (dry) can be obtained with normal haulage and disposal equipment traffic on dumps constructed in 24-inch lifts. Mechanical compactors can be used to provide a dry density of 90 pcf to the exterior of the pile. As production begins, field compaction and density tests will be made. Results will be used to improve pile design.

The results of permeability tests on a mixture of 65% TOSCO II processed shale and 35% Paraho processed shale follow an expected trend under compacted densities of about 90 pcf. Semi-pervious to impervious permeabilities were obtained. Permeability was shown to decrease as the pile depth increased. Samples classified as impervious (under 8000 psf surcharge to simulate burial at a depth of approximately 90 ft.) had permeabilities that ranged from 0.3 to 0.6 feet per year. The studies also indicated that increasing fines would decrease permeabilities. Therefore, the processed shale disposal pile consisting of 100% TOSCO II processed shale should be essentially impervious which will prevent saturation. Water samples of the leachate were obtained at various time intervals throughout the permeability tests. Chemical analysis of these samples are shown in Table 4-2-2.

Table 4-2-2

CHEMICAL ANALYSIS OF LEACHATE
(In milligrams per liter)

Time Intervals (in hours)	Ca	Mg	Na	CO_3	HCO_3	SO_4	Cl	Fe
0- 96	300	44	1350	70.1	520	3750	95	0.21
96-145	290	28	900	30.0	310	1080	41	0.28
145-220	200	24	650	36.0	240	1610	27	1.20

2.3 SITE LOCATION AND AREAL REQUIREMENTS

Selecting the most desirable location for the surface disposal of processed shale from surface retorting required consideration of the following criteria:

- Environmental impact.
- A site of sufficient size to contain all of the processed shale.
- Location in which processed shale could be stabilized and rehabilitated as soon as possible.
- An on-tract location that would not unduly restrict MIS retort development.
- Reasonable proximity to the surface retorts.

Rinky Dink Gulch (Figure 4-2-1) was selected as the most suitable location to satisfy these criteria.

A storage area of 880 acres will be required to contain the volume of material produced during this project. Any use of processed shale to fill MIS retorts will reduce the height and/or size of the disposal pile. Constructed side slopes will be dressed to a final slope of approximately 4:1, which is required for effective revegetation. Pile volumetrics by years are shown in Table 4-2-3.

Table 4-2-3

PROCESSED SHALE DISPOSAL PILE

Year	Volume $yd^3 \times 10^6$	Cum. Vol $yd^3 \times 10^6$
1	9.95	9.95
2	9.98	19.93
3	9.22	29.15
4-5	18.07	47.22
6	8.93	56.15
7-10	38.13	94.28
11-15	53.98	148.26
16-30	161.74	310.00

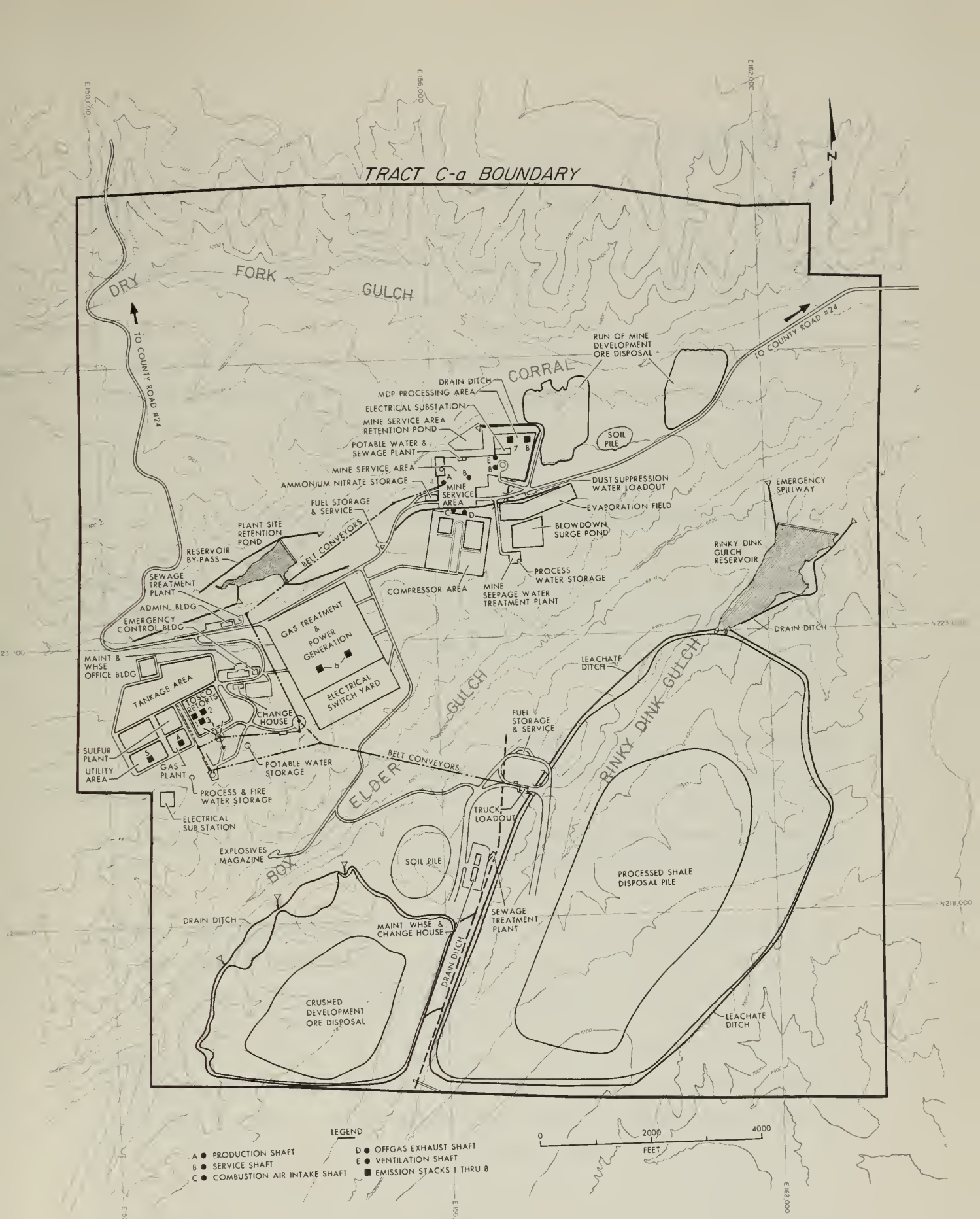


Figure 4-2-1

SITE PLAN

2.4 SITE PREPARATION

Soil removal and cover requirements play an integral part in the overall site preparation and disposal operations. Stripped soil will be stored, revegetated, reclaimed, and used in the rehabilitation of the processed shale disposal pile.

Soil storage facilities will be provided west of the Rinky Dink Gulch disposal area. The soil storage pile will be conical shaped with 4:1 side slopes and will be revegetated to prevent erosion.

2.5 PROCESSED SHALE CONDITIONING, TRANSPORT AND PLACEMENT

Processed shale from the surface retorts will be cooled in a rotary tube cooler by the addition of water (Section 3, Processing). Processed shale moisturizing adds about 14% by weight water and cools the material to about 200^{o} F.

The moisture will be provided from scrubber foam, stripped foul water, and process water as required. The water will be absorbed by the processed shale with some loss by evaporation. The cooled processed shale will be delivered from the moisturizer to belt conveyors and will be transported to a truck loadout hopper.

The truck loadout hopper will be designed with three (3) 150-ton capacity compartments having nearly vertical sides. These features are required to prevent bridging and plugging of processed shale at the exit gate. Processed shale will be transferred into the bin compartments by a series of hydraulically actuated plows controlled by bin level sensors. Emergency storage will be provided by an automatic bin overflow system which delivers material to a surface storage pile. Front-end loaders will be used to reclaim this material.

Processed shale will be transported to the disposal site in 150-ton bottom-dump trucks or large rubber tire scrapers. The disposal operations

will be scheduled concurrently with retort operations. In 1987, six trucks or an equivalent number of scrapers will be required for disposal operations.

The trucks or scrapers will deposit the processed shale on the disposal pile in windrows which will be spread in about 24-inch lifts by a grader. The interior 80% of the pile can be compacted to an estimated 85 pcf by the haulage trucks or scrapers. The exterior 20% of the pile will be compacted to an estimated 90 pcf by mechanical compactors to ensure stability and make the outer portion of the pile impervious. The entire processed shale pile will eventually be completely overlain by coarse material and soil. The coarse material acts as a barrier preventing capillary transport of dissolved salts from the processed shale to a final soil cover over the coarse material (Section 6, Chapter 8, Land Rehabilitation). The side slopes will be dressed to 4:1 by dozing and grading. A system of ditches and retention ponds will be used to control pile runoff and leachate as discussed later in this chapter (2.8 Water Control).

2.6 MAJOR EQUIPMENT SELECTION, STRUCTURES AND CIVIL WORK

Major equipment, structures and civil work needed for processed shale disposal will be determined on consideration of the following factors:

- Material characteristics.
- Reliability and dependability.
- Economic and environmental requirements.

Equipment and structures associated with the Commercial Phase processed shale disposal are the processed shale belt conveyors and an elevated truck loadout hopper. The processed shale belt conveyors will be conventionally designed with semicircular hoods and necessary safety devices, and will transport processed shale from the shale conditioners to the truck loadout hopper. The belt conveyors will be supported by

standard steel truss sections and will be equipped with side walkways and necessary safety devices. The elevated truck loadout facility will be a three-compartment hopper designed for bottom-gate truck loading. The hopper will be constructed of structural steel and steel plate and will contain bin level sensors for distribution control. An automatic overflow chute to surface stockpiles will be included to ensure continuous operation of the conveyor system. The surface storage piles will be contained by a concrete wall.

Civil construction will consist of roads, foundation excavation and site grading for the processed shale belt conveyor system, the truck loadout hopper, the water diversion facilities and the disposal site preparation. Haul roads will be designed to the specifications and performance criteria of the haulage equipment and Bureau of Land Management (BLM) requirements. Minimum horizontal curvature of 240-foot radius and maximum vertical gradient of 8% are included in the design. The haulage roads will be 80 feet wide, with an additional 25 feet for shoulders and a non-traversable safety berm wherever access roads parallel the haulage roads. The haulage road routing is shown on the Site Plan (Figure 4-2-1).

2.7 REHABILITATION

Rehabilitation efforts will be directed towards reclamation and revegetation of disturbed areas resulting from construction of roads, pipelines, transmission corridors, and ancillary facilities. Revegetation of the processed shale disposal pile will be aided by the construction of an artificial soil profile (see Section 6, Chapter 8, Land Rehabilitation). The acreage of disturbance for each area and the proposed schedule of revegetation of that acreage is presented in Section 6, Chapter 8, Land Rehabilitation.

The areas of greatest disturbance will occur along haul and access roads which will result in the disturbance of a number of vegetation types. The revegetation technology which is available for reclamation in these

areas is described in detail in Section 6, Chapter 8, Land Rehabilitation. Abandonment of the disposal pile will require little more than completion of the rehabilitation-revegetation activities that will continue throughout the project (Section 6, Chapter 14, Abandonment).

2.8 WATER CONTROL

The control of water in and around the Rinky Dink Gulch disposal area will pertain to the following categories: surface water derived from land adjacent to the disposal area and contaminated water received from the waste disposal area. Surface water runoff (storm drainage) and contaminated water (disposal pile runoff and leachate) are discussed in Section 5, Chapter 5, Water Management and Section 6, Chapter 6, Water Quality Control. Erosion control of the disposal piles is discussed in Section 6, Chapter 8, Land Rehabilitation.

2.9 AIR QUALITY CONTROL

Dust will be controlled by water sprinkling or other suppression methods. Air quality for the disposal operation is discussed in Section 6, Chapter 5, Air Quality Control.

CHAPTER 3
DEVELOPMENT ORE DISPOSAL OPERATION

3.1 DEVELOPMENT ORE DISPOSAL

Disposal sites for development ore, run of mine (ROM) and crushed ore, from the underground retorts were selected on the following basis:

- Minimum environmental impact.
- Sites large enough to contain the development ore.
- Sites that could be rehabilitated.
- On-tract locations that would not restrict MIS retort development.
- Reasonable proximity to the mining area for ROM disposal during MDP.
- Reasonable proximity to the end of the conveyor and the processed shale disposal area for crushed development ore.

The area to the north and east of the mine area was selected for the ROM material during the early years of the MDP.

An area in the southwest corner of Tract C-a was selected for the crushed development ore.

Development ore is either ROM, nominal size 24" and under, or crushed, 8" and under. During the early years thru 1984, the material removed from the underground mine will be ROM size. An area of about 65 acres will be required to store the 5 million tons of ROM material that will be produced. Disposal operations will begin by stripping and stockpiling the soil from an area that will be used initially. Material will be moved from the mine shaft by truck to the ROM disposal site. Disposal piles will be developed by rear dump trucks discharging ore at the top elevation along the slope of Corral Gulch. The exterior surfaces

will be shaped to blend with the surroundings and sloped at 4:1. The surface will be covered with about 12 inches of soil and revegetated.

During 1985 and 1986, the material removed from underground will be crushed to 8 inch maximum size. An area of about 260 acres will be required to store the 27 million tons of crushed development ore that will be produced. Disposal operations will begin by stripping and stockpiling the soil from an area that will be used initially. The crushed development ore will be moved from the mine shaft by the conveyors that will be used in the Commercial Phase to move ore to the TOSCO retorts and processed shale to the disposal area. From the end of the conveyor system the ore will be trucked to the disposal area and handled in the same manner as the ROM material above. Reclamation will be handled in the same manner as the ROM piles except that portions of the pile, that will be used in the artificial profile on the process shale pile, will not be reclaimed until the processed shale pile is completed and reclaimed.

Surface water runoff (storm drainage) from the development ore piles is discussed in Section 5, Chapter 5, Water Management and Section 6, Chapter 6, Water Quality Control.

Dust will be controlled by water sprinkling or other suppression methods. Air quality for this operation is discussed in Section 6, Chapter 5, Air Quality Control.

Rehabilitation and revegetation of the ore piles is discussed in Section 6, Chapter 8, Land Rehabilitation.

SECTION 5
SUPPORT FACILITIES

CHAPTER 1
INTRODUCTION

Support facilities for development of Tract C-a will include roads, power transmission line, water supply and distribution system, product pipeline, communications system, fuel storage facilities and several buildings. Each major project activity (mining, processing, disposal) has its own internal support systems unique to that particular activity. These systems are discussed in the respective section describing that activity, and will not be repeated here.

The locations of most project support facilities are, of course, controlled by the locations of the major project features: mine, processing facility, and processed shale disposal area. Areal relationships among these facilities are shown in Figure 5-1-1 which also depict routes of the product pipeline, power transmission line and the Ryan Gulch and Rangely access roads (County Road 24).

Most of the truck traffic carrying equipment, materials and supplies to Tract C-a will travel from Rifle via State Highway 13, the Piceance Creek road and County Road 24 (Ryan Gulch road). Smaller amounts of truck traffic will probably reach the tract via the Rangely access road from the west and via Meeker, State Highway 64, the Piceance Creek road, and the Ryan Gulch road from the north.

Rifle is situated on the mainline of the D&RGW railroad. Goods shipped by rail will most likely be shipped to that area to be loaded on trucks for final transport to Tract C-a.

Most people employed by the Rio Blanco Oil Shale Project will probably live in Rangely if the Rangely access road is installed but some may choose to live in Meeker or Rifle. The Rangely access road will drastically reduce the driving distance between Rangely and the tract, but the

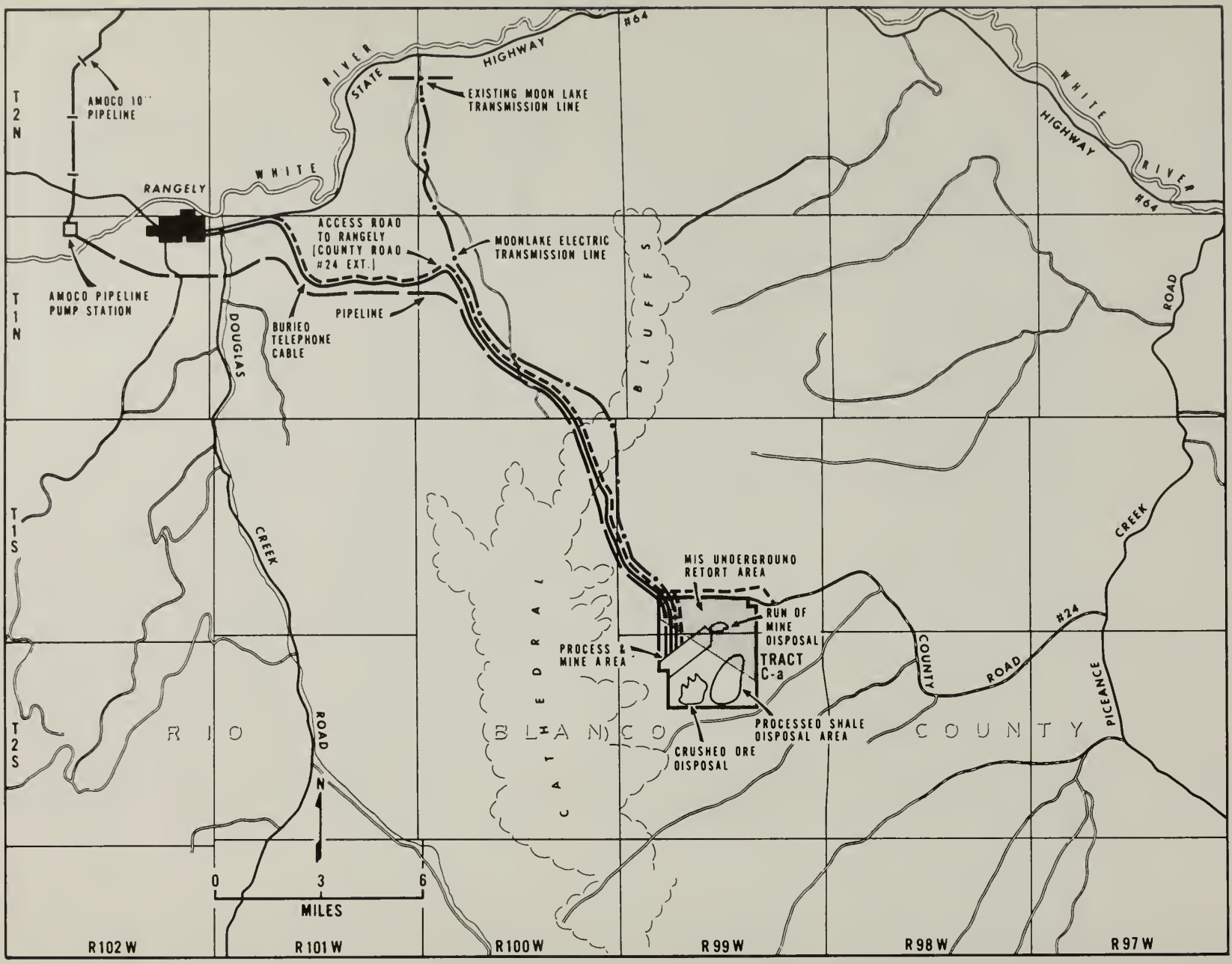


Figure 5-1-1
LOCATION OF RBOSP FACILITIES

commuting distance for employees living in Meeker and Rifle will remain the same as it is today. Roads are discussed in more detail in Chapter 2.

Power demand during the Modular Development Phase (MDP) will range from about 4 MW during early construction, dewatering and mine development activities, to a maximum of about 40 MW during the period when MDP operations plus construction and development activities for the Commercial Phase peak. The primary power source is Moon Lake Electric Association's existing 138-KV line along the White River about 20 miles north of Tract C-a. A 138/230 KV transmission line will be built from this line to the tract. For the most part, the new line will occupy the same corridor as the Rangely access road and the product pipeline. On-site diesel engine driven generators will be installed to supply the power required prior to completion of the transmission line and delivery substation. These units will be retained as emergency power sources.

While electrical power requirements for Commercial Phase operations are significantly greater, it is planned that these requirements will be largely offset by on-site generating facilities using low-BTU gas from the Modified In Situ retorting process. About 100 MW of electrical demand from utility sources is anticipated for a Commercial Phase operation. Power supply and distribution are described in Chapter 3.

In the MDP, shale oil will be trucked from Tract C-a and transported to a market. In the Commercial Phase 76,000 BPSD of shale oil will be transported by pipeline to Amoco's pipeline facilities near Rangely. From there it will be transported through Amoco's existing 10-inch pipeline to other connecting carriers for ultimate delivery to refineries in the West and Midwest. The product pipeline is described in Chapter 4. By-product sulfur (265 LTPSD) will be shipped from the tract by truck.

Water for the MDP and Commercial Phase will be obtained largely from groundwater sources on the tract. Normal mine dewatering operations will provide most of the required amount while the remainder will be

derived from water produced in the MIS retorting operation or from surface drainage. Water management is described in Chapter 5.

Telephone service will be provided by Mountain Bell Telephone Company by extending existing facilities from Rangely. Communications are further described in Chapter 6.

A single transportation and utility corridor stretching from the junction of Ryan Gulch and Piceance Creek on the east to the Rangely area northwest of the tract will serve the needs of RBOSP in both MDP and Commercial Phase (see Figure 5-1-1). Although not presently planned, another corridor for an alternate power supply from a different source may be needed to insure a more reliable power supply during the Commercial Phase.

The eastern part of the Ryan Gulch-Rangely corridor contains the access road. From Piceance Creek, the corridor follows existing County Road 24 to the historic Ryan Gulch School where the corridor turns northwest and crosses the Yellow Creek-Piceance Creek divide. The corridor then crosses Stake Springs Draw just south of its confluence with Corral Gulch and turns west to Tract C-a just west of the abandoned 84 Ranch. From Tract C-a to the Rangely area, the corridor contains the access road, telephone cable, product pipeline and the power transmission lines. The corridor continues west for nearly two miles on Dead Horse Ridge before curving to the northwest, then successively crosses Big and Little Duck Creeks and several smaller drainages in between. It then crosses Calamity Ridge about one-half mile beyond Little Duck Creek and drops down into the East Fork of Spring Creek. It follows Spring Creek for about seven miles where the road, telephone cable and product pipeline turn and extend westward for some three miles before entering Gillam Draw. The power line continues down Spring Creek for about three miles, turns north and follows Calamity Ridge to Moon Lake's existing line which is about one mile south of the White River and eight miles northeast of Rangely.

The road continues along Gillam Draw to State Highway 64, three miles east of Rangley. The product pipeline leaves Gillam Draw about a mile south of State Highway 64 and continues westward, south of Rangely, to Amoco's pipeline facilities west of Rangely.

The Bureau of Land Management must approve the exact routes of these facilities. The final alignment of these facilities may differ somewhat from that described above and shown on Figure 5-1-1.

CHAPTER 2
TRANSPORTATION

2.1 ORIGIN AND DESTINATION OF GOODS AND PEOPLE

The bulky machinery and equipment to be used or installed during construction, plus materials and supplies necessary for construction and operation, will originate outside the northwest Colorado area. Whatever their origin, heavy and/or bulky items will probably be shipped by rail. There is currently no rail service to the interior of the Piceance Creek basin and none is planned by RBOSP. The nearest railheads are the Denver and Rio Grande Western Railroad (D&RGW) spur line at Craig and the mainline at Rifle. A new rail section from Craig south to Axial is now being designed. If built, this section will bring rail service about 23 miles closer to Tract C-a. Even so, it is not economically feasible to extend rail service to the tract from either Rifle or Axial.

Because the highway distance from Rifle to Tract C-a is nearly 30 miles shorter than from Axial to the tract and because Rifle is on the mainline rather than a spur, the Rifle area is the logical choice as a destination for goods shipped by rail to Tract C-a. A new railroad siding will be built in the vicinity of Rifle to handle the rail traffic serving Tract C-a. RBOSP is currently in the process of selecting an exact location for the siding. Trucks will transport goods from the siding to the tract.

Goods shipped by rail from the west or southwest will most likely pass through the Salt Lake City area, then south and east through Price, Green River, Grand Junction and finally to Rifle. From the south and east, goods can travel by rail through either Pueblo or Denver, then to Glenwood Springs and Rifle.

Goods shipped entirely by truck can reach the corridor serving Tract C-a by a number of different routes as shown in Figure 5-2-1. Trucks originating in Salt Lake City or points west will likely reach the tract via Vernal and Rangely rather than swinging south through Grand Junction and Rifle. Trucks from Denver and other points east or south, which will likely constitute most of the truck traffic serving Tract C-a, will pass through Rifle on their way to the tract. Thus, Rifle will likely be a focal point for truck and rail transportation during construction and operation.

Most of the Tract C-a construction and operating personnel are expected to reside in Rangely if the Rangely access road (extension of County Road 24) is constructed. The Rangely access road will reduce the current highway distance from Rangely to Tract C-a by more than 40 miles and thus substantially reduce commuting time. For those choosing to live in Meeker or Rifle, the commuting distance will not change from what it is now.

Estimated one-way driving distances and commuting times for employees at the project are shown below:

	Miles	Minutes
Rifle	58	73
Meeker	51	71
Rangely (present road)	68	94
Rangely (new road)	25	30

2.2 ROADS AND HIGHWAYS SERVING TRACT C-a

The principal highway routes serving Tract C-a will extend from Rifle on the southeast to Rangely on the northwest. The route follows State Highway 13 from Rifle to Rio Blanco, then turns northwest on Piceance Creek road (County Road 5) to County Road 24, west to the historic Ryan Gulch School, then turns northwest over the Yellow Creek-Piceance Creek

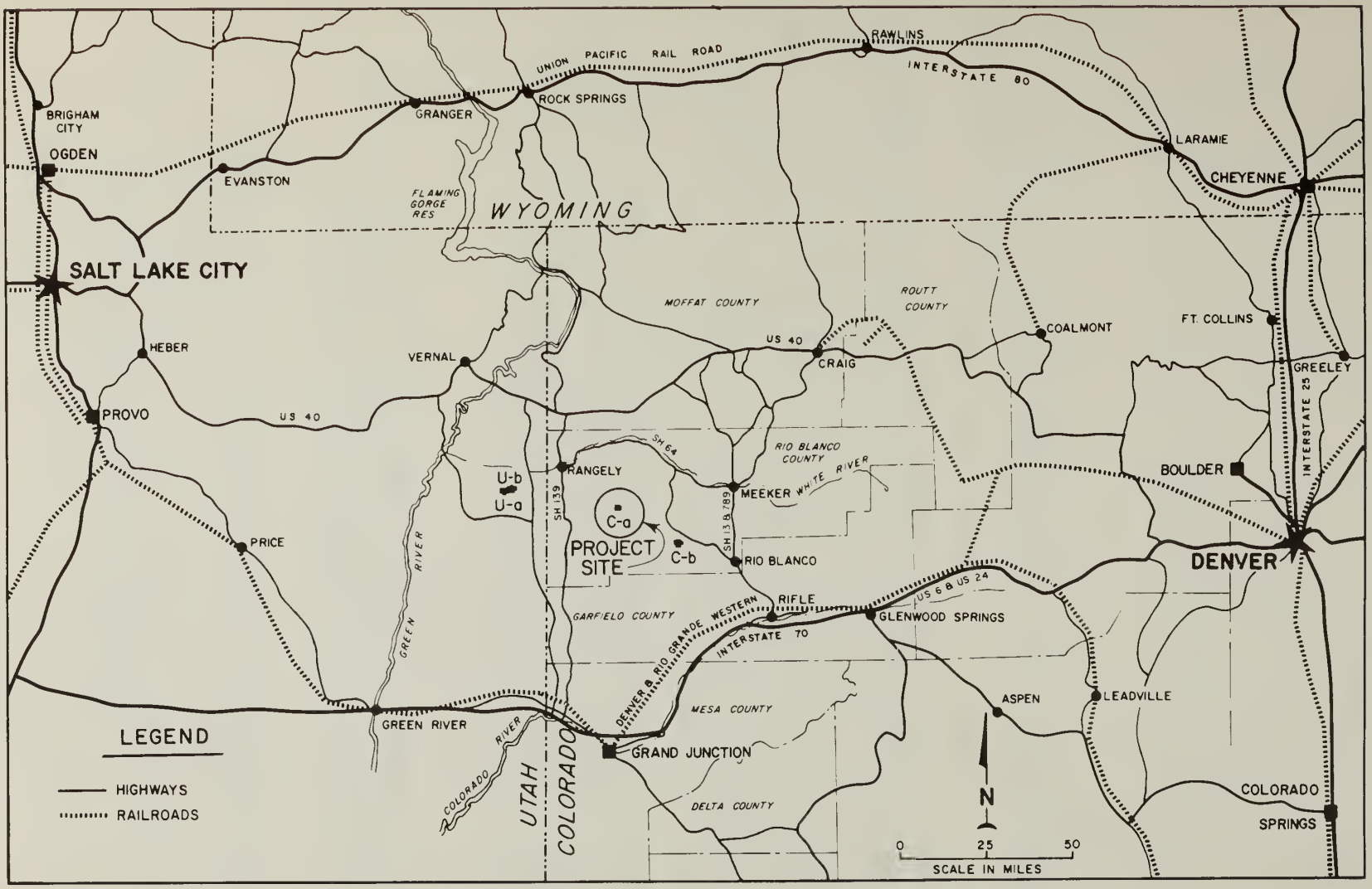


Figure 5-2-1

REGIONAL MAP SHOWING LOCATION OF TRACT C-a

divide and on west to the processing facility at Tract C-a. There, it connects with the planned extension of County Road 24 to State Highway 64 and then west to Rangely. This route will provide access during both the Modular Development and Commercial Phases. The condition of, and necessary improvements to, roads along this route are described in the following paragraphs. Other roads and highways in the area will carry very little traffic directly associated with the Rio Blanco Oil Shale Project.

A. State Highway 13 - Existing Colorado State Highway 13 in Rifle is not adequate to handle the anticipated heavy truck traffic associated with energy development in the Piceance Creek basin and other areas north and west of Rifle. Several alternatives are being considered by the Colorado Department of Highways and the City of Rifle for routing heavy truck traffic either through or around Rifle. State Highway 13 between Rifle and Rio Blanco will carry the bulk of the heavy truck traffic serving Tract C-a. The geometric design of this section of highway is adequate, but the roadway is in poor structural condition in many places. Six concrete box culverts and a bridge on this section of highway are all structurally adequate to carry the anticipated loads. However, the bridge over Piceance Creek just south of Rio Blanco may be too narrow to accommodate the few oversized loads expected to be shipped to the tract. A temporary crossing of Piceance Creek may be required for the occasional oversize load.

B. Piceance Creek Road - Rio Blanco County Road 5 (better known as the Piceance Creek road) from Rio Blanco to Ryan Gulch is 22 feet wide. It was upgraded with a new asphalt surface overlay in late 1976.

The Piceance Creek road is basically a 50-mph facility although the speed limit is reduced in several areas because of sharp curves. In addition to numerous metal culverts, there are 20 bridges on the Piceance Creek road. All are in good condition and, according to bridge structure ratings of the American Association of State Highway and Transportation Officials, can be expected to carry maximum legal Colorado highway loads.

C. Ryan Gulch Road - The Ryan Gulch road (or Rio Blanco County Road 24) as it currently exists would be classified as an unimproved county road. Although some sections between the historic Ryan Gulch School and Tract C-a were upgraded in 1975, none of it is paved. A dust-free, paved surface, plus a new bridge over Piceance Creek will be necessary before the heavy traffic associated with Tract C-a development begins. Improvements to the Ryan Gulch road so that it can safely handle the anticipated traffic are discussed in more detail in a report prepared by Morrison-Knudsen Company, Inc. entitled "Access Road, Tract C-a to Meeker/Rifle via County Road 24", dated November 21, 1975. This report has been furnished to the AOSS.

D. Rangely Access Road - RBOSP has conducted socio-economic studies which indicate that Rangely should logically be established as the residence of most RBOSP employees, rather than Meeker or a new town. Rangely is an oil town which didn't exist until the 1940's when development of the Rangely oil field began. Its current residents are accustomed to oil-related development and want the infusion of oil shale workers.

Consequently, RBOSP has studied highway access from Tract C-a to Rangely in considerable detail. The conclusion is that an extension of Rio Blanco County Road 24 (the Ryan Gulch road) from the tract to Rangely will provide badly needed access from the west and will also result in the following:

- A reduction of about 43 miles in driving distance and about 70% in commuting time from Rangely to the tract, which also means greater safety.
- Substantial road user savings, including an annual savings of more than 800,000 gallons of gasoline by employees commuting from Rangely.
- Improved growth potential for Rangely and better population distribution among established communities.

The need and justification for the Rangely access road is discussed in more detail in a report prepared by Morrison-Knudsen Company, Inc., entitled "Access Road, Tract C-a to Rangely", dated November 14, 1975. This report has also been furnished to the AOSS.

E. State Highway 64 - State Highway 64 between Meeker and Rangely will carry very little traffic associated with Tract C-a development. Although routine maintenance in a few areas and straightening of some winding sections would improve riding comfort, the highway is adequate as it now exists and no changes are anticipated because of the Rio Blanco Oil Shale Project.

2.3 INTERNAL ROAD SYSTEM

RBOSP's internal road system will consist of haul roads for transporting mine development material and processed shale to disposal, and various service and access roads serving the mine, processing facility and processed shale disposal area. In contrast to the public road system discussed in preceding paragraphs, the internal road system will be constructed and paid for by RBOSP. Safety and efficiency are the controlling factors in the ultimate design and location of all internal roads.

A maximum vertical gradient of 8% will be used on all internal access and haul roads. Grades of 10% will be used on several short sections of service road to avoid excessive land disturbance. Vertical curvature on access roads in the internal road system will be designed for safe stopping at a speed of 30 to 50 mph. Horizontal curvature will vary from a radius of 100 feet for service roads to 250 feet for haul and access roads.

A. Modular Development Phase - Access to the Modular Development Phase facility will be an extension of existing County Road 24 from the east

tract boundary in Corral Gulch. It will follow Corral Gulch west until it climbs to the operating area. This road will serve as secondary access in the Commercial Phase.

B. Commercial Phase - Primary public access during the Commercial Phase will intersect the proposed extension of County Road 24 near the northwest corner of Tract C-a and follow its western boundary to the mining and processing complex.

2.4 REGULATION OF ACCESS

In compliance with lease stipulations and BLM regulations, existing roads and trails will be left open until they enter an area that presents a potential safety hazard to the public. Suitable access to safe water impoundments and non-operating areas will be provided to encourage safe use of the area by the public. Controls will be established to prevent access by the public to areas such as contaminated water storage ponds, unstable slopes, haul roads, construction areas, etc., where hazards may exist. The type of control used will depend on the degree of potential hazard but could include posting signs, barricading roads, or fencing the area. During construction, flagmen or other warning procedures will be used, as necessary, to protect the public. Fences will be provided to ensure the safety of the public. Access to the processing facility and the mine will be controlled by security gates located west of the administration building and east of the mine.

An existing road (County Road 24) runs up Corral Gulch from 84 Ranch to the tract. Signs placed along this road west of its intersection with the proposed extension of County Road 24 to Rangely will warn the public that the road is closed ahead. A gate will be placed across the road at the eastern tract boundary.

2.5 OFF-ROAD - VEHICLE USE

Use of off-road RBOSP vehicles will be restricted. Existing and potential trails that may be used by off-road vehicles will be identified and posted with restrictive warning signs. In some locations fences, mounds, trenches or other physical devices will be installed to prohibit use. Where public access is affected, areas will be closed to off-road vehicles only with the approval of the BLM and AOSS.

CHAPTER 3
POWER SUPPLY AND DISTRIBUTION

3.1 POWER DEMAND

A. Modular Development Phase (MDP) - Power demand during the MDP is estimated to be as follows:

Year	Power Demand MW
1978	4
1979-1981	9
1982	12
1983-1986	40

Initial mine development and construction activities require 4 MW of power. Power demand will increase to 9 MW in 1979 when MDP operations begin, and will increase again to 12 MW by 1982. During the period between 1983 and 1986, intensified construction and development operations will increase the power demand to approximately 40 MW.

B. Commercial Phase - Total power demand during the Commercial Phase is significantly greater than during the MDP. The increased capacity will be furnished by on-site generation (about 225 MW) utilizing the MIS retort off-gas augmented by approximately 100 MW of imported power.

3.2 SUPPLY SOURCE

Tract C-a is located within the service area certificated to Moon Lake Electric Association, Inc., by the Colorado Public Utilities Commission. Moon Lake is thus the exclusive distributor of utility-source electricity to the Rio Blanco Oil Shale Project. As of January 1975, Moon Lake

owned and operated a total of 331 circuit miles of 69-KV and 138-KV transmission lines with a total system load of about 60 MW. Its present generating facilities consist of two small hydroelectric plants with a combined output of 2.1 MW. The Association has historically satisfied the bulk of its system requirements by purchasing power from wholesale suppliers. Moon Lake is a member of the Intermountain Consumer Power Association, and through this association, purchased most of its power for resale during 1974 from the Colorado River Storage Project of the U.S. Bureau of Reclamation. Figure 5-3-1 shows Moon Lake's 1975 transmission system, interconnections with Utah Power and Light Company, Colorado-Ute Electric Association, Inc., and the USBR, and proposed system additions through 1988.

Moon Lake is currently buying additional power from Utah Power and Light and plans to use this source to satisfy RBOSP requirements.

Actual commitment for the purchase of power from Moon Lake will be negotiated when power requirements are confirmed, but RBOSP will work closely with Moon Lake to allow adequate lead time to provide for Tract C-a demand.

A. Modular Development Phase - Installation of power lines will begin in 1977, but power will be needed at the tract for mine development and construction activities prior to completion of the power supply lines. The power needed for these activities (about 4 MW) will be provided by diesel-powered generators installed on-site.

B. Commercial Phase - Power (about 225 MW) will be generated on-site with the MIS retort off-gas. This generation capacity will be augmented with the Moon Lake supply (about 100 MW) provided over lines installed during the MDP.

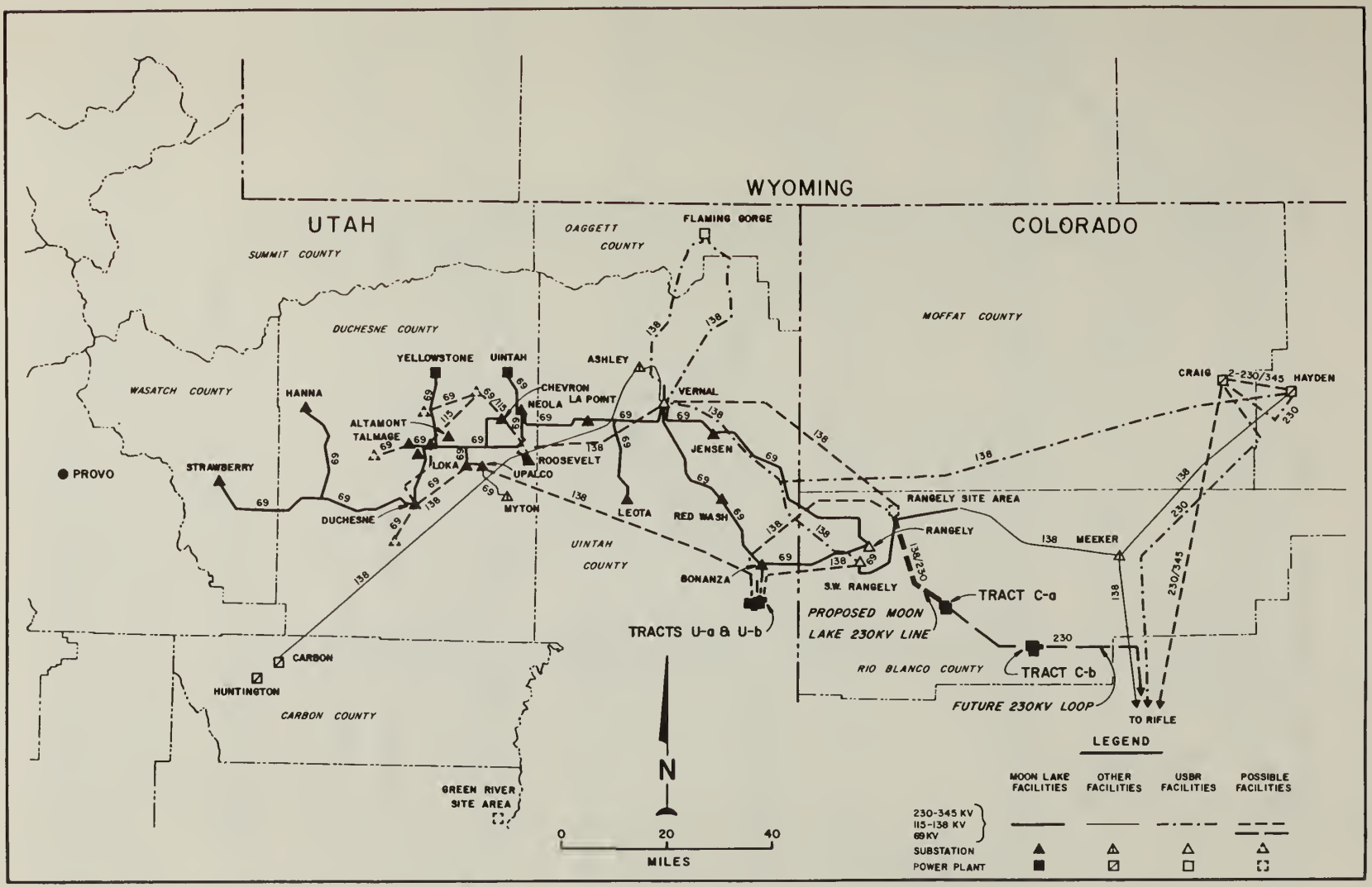


Figure 5-3-1

MOON LAKE ELECTRIC ASSOCIATION, INC. SERVICE AREA

3.3 DELIVERY TO TRACT C-a

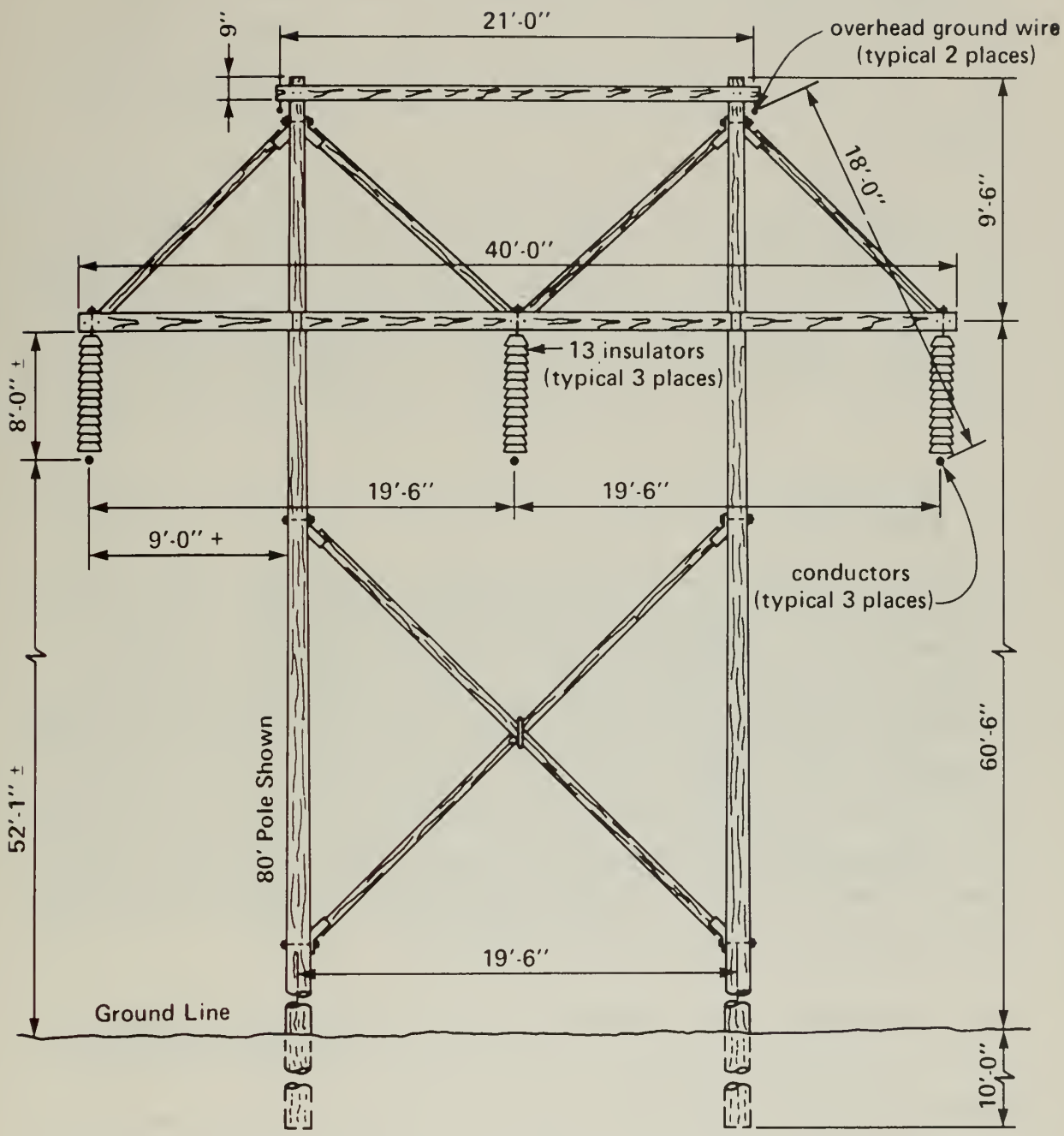
A. Modular Development Phase - Moon Lake's basic plan is to tap an existing 138-KV line on the White River approximately eight miles east of Rangely. Some 22 miles of single-circuit, 230-KV transmission line will be built between there and Tract C-a. The anticipated route of the line is shown on Figure 5-1-1, but the alignment won't be finalized until the BLM approves Moon Lake's right-of-way application.

In any event, the line will terminate at RBOSP's main substation at the tract. The basic pole structure used will be the standard REA type shown in Figure 5-3-2, although several other types of structures will also be used over rough terrain and at points where the line changes direction. The basic 2-pole structures will vary in height with changing terrain, but will stand approximately 60 feet high and be set in the ground from 8 to 10 feet, depending on soil conditions. Raptor perches will not be provided since the distance between lines will be about 20 feet. The 230-KV line from the White River tap point will be operated at 138-KV during the MDP. Space will be provided in the project substation for future installation of autotransformers, should transmission line voltage be increased to 230-KV.

B. Commercial Phase - No additional delivery facilities are presently planned for the Commercial Phase. An alternate power supply from a different source may be needed to insure a more reliable power supply during this phase. The location and timing for this line will depend on other developments in the area.

3.4 POWER DISTRIBUTION AT TRACT C-a

Power distribution lines within the RBOSP project area will be designed in accordance with REA standard V-C-1. Raptor protection will be provided pursuant to REA bulletin 61-10.



230 kV H-Frame Two-Pole Structure
REA Type TH-230

Figure 5-3-2

TYPICAL POLE STRUCTURE FOR USE ON MOON LAKE TRANSMISSION LINE TO TRACT C-a

A. Modular Development Phase - Moon Lake's point of delivery is in the main substation just south of the Commercial Phase Retort facility. Four primary 34.5-KV distribution circuits will be required during the MDP. Two of these circuits will supply loads in the mine service area and two will supply dewatering wells and other scattered loads on the tract.

B. Commercial Phase - The number of circuits required for Commercial Phase operations cannot be accurately determined at this time. However, it is known that there will be two 34.5-KV circuits to the TOSCO II processing area and two 138-KV circuits to the compressor and mine service areas.

3.5 STANDBY POWER

Power outages may be caused by a number of circumstances, such as loss of generation or a transmission line, transformer failure, or other control malfunction. Some will be of short duration and have little effect on operations; but others, such as loss of a transmission line or transformer, may cause long delays in full operations. Power failure will affect all operations and only self-powered vehicles and facilities with standby power will be able to continue operating. Without standby power in certain critical areas of the mining and processing operations, personnel and/or equipment may be endangered.

The diesel engine driven generators installed for the initial power supply in the MDP will be retained and connected to serve as a standby power source for the project.

CHAPTER 4
PRODUCT PIPELINE

The primary product from the Rio Blanco Oil Shale Project (pipelineable shale oil in the Commercial Phase) will be transported to Amoco's pipeline facilites near Rangely via a 26-mile, 10-inch product pipeline. From there it will be transported through Amoco's existing 10-inch pipeline to other connecting carriers for ultimate delivery to refineries in the West and Midwest. During the Modular Development Phase, the shale oil will be trucked to a market point.

The product pipeline will be designed for a capacity of 76,000 BPSD.

The route of the pipeline is shown in Figure 5-1-1. Wherever feasible it will be installed immediately adjacent to the Rangely access road until the road swings north about 3-1/2 miles southeast of Rangely to connect with State Highway 64. At this point, the pipeline will continue to the west, then gradually swing to the northwest across the White River and terminate at Amoco's pump station about two miles west of Rangely. Where the pipeline forks away from the Rangely access road, it will follow other utility lines in established corridors for the remaining distance to the Amoco pump station

4.1 PIPELINE DESCRIPTION

The pipeline, pumping facility and tankage will be designed and constructed in strict compliance with all Federal, State, and local regulations and industry codes. The following is a listing of some of the most important:

- Oil shale lease and environmental stipulations attached thereto.
- Department of Transportation regulations for liquid pipeline systems, Title 49 CFR Part 195.

- Federal Communications Commission--Rules and Regulations.
- OSHA--Title 20 CFR Part 1910.
- American National Standards Institute codes B31.4, B16.5, B16.9.
- API 5L, 5LX, 2531, 2534, 6D, and 12D.
- National Association of Corrosion Engineers RP-01.
- National Fire Protection Association Flammable and Combustible Code-30.

A. Equipment - The pipeline will consist of 10-3/4 inch O.D., 0.219-inch wall thickness, API Grade B carbon steel linepipe for the first 17 miles after it leaves the pumping station at Tract C-a. The remainder will be 10-3/4 inch O.D., 0.250-inch wall thickness, API Grade X-42 carbon steel linepipe because of higher pressures in the pipeline due to a greater elevation differential on the western end of the line. The pipe will be manufactured to API Code 5L and 5LX specifications and comply with Department of Transportation regulations, Part 195.

All mainline shut-off valves will be built to comply with API Standard 6D and will be ANSI 600 lb. class rated to operate at a maximum pressure of 1440 psi.

The main pumping station will be located near the tankage area of the processing facility on Tract C-a. Electric motor driven centrifugal pumps capable of delivering 76,000 BPSD will be installed. A spare pump will be provided.

Relief valves and high-pressure shutdown devices will be installed, as needed, on the pipeline and at station facilities.

Positive displacement meters will be installed at Rangely for custody transfer and measurement of product delivered by the RBOSP pipeline to Amoco Pipeline Co. A mechanical displacement prover will be installed for calibration of these meters.

The pipeline will be fed from a blending station at the Tract C-a processing facility. At the Rangely end of the pipeline, the product will be stored in two 50,000-barrel tanks in order to segregate the shale oil from other oil in Amoco's pipeline system.

B. Electrical Equipment and Safety Monitors - Distribution voltage to the pump station will be 34.5-KV 3-phase power.

A transformer bank consisting of three transformers rated 34.5-KV to 2300 volts will be installed to supply power for the pumps.

Electric motors will be equipped with motor bearing temperature monitors set to shut down units should the maximum allowable bearing temperature be exceeded. The pump bearings and pump case will also be equipped with temperature monitors. The pump will be protected for low suction and high discharge pressure and high flow rate, and against excess vibration.

4.2 CONSTRUCTION

A. Preparation and Use of Right-of-Way - As noted earlier, the pipeline will follow the road over most of the route between the tract and Rangely. In especially rough terrain, the pipeline will be buried in the roadway shoulder or in a rock ditch; in other areas, it will be installed as close to the road as possible. In those places where the pipeline is not adjacent to the road, a maximum of 50 feet of right-of-way will be required.

Clearing of the right-of-way (ROW) before digging the pipeline ditch will be minimized and will only be done in areas where removal of brush and trees is necessary. Disturbance of land outside the ROW will be avoided. Any trees removed from the ROW will be disposed of in compliance with BLM requirements. For example, slash from cuttings could be stacked

for later scattering on the ROW after reseeding. There will be no burning of slash along the ROW without prior approval from appropriate regulatory agencies.

Where gaps are to be cut in fences, or existing gates and/or cattle guards are to be widened, fences will be properly braced so that they will not become slack when cut. Any gates, cattle guards, or fences which are damaged will be repaired.

During construction, pipe shall be strung along the right-of-way so as to cause the least possible interference with the normal use of the land crossed. Gaps shall be left at frequent intervals to permit the regular use of the land and for the passage of equipment, vehicles, cattle and wildlife.

B. Ditches - The pipeline ditch will be no wider than 24 inches (except in rock) and deep enough to provide a minimum of 36 inches of cover over the pipe. The ditch will be appropriately deeper where the pipeline must pass beneath another pipeline or other underground facility to provide at least 12 inches of clearance; sandbags will be installed at such crossings to ensure clearance between the facilities. Ditches in rock will be at least 28 inches wide; some blasting may be required in areas where rock is encountered.

C. Welding - All welding will comply with the latest edition of API Standard 1104, "Standard for Welding Pipeline and Related Facilities." Welders will be qualified pursuant to tests outlined in API 1104. All welds will be radiographically inspected during construction of the pipeline and frequent destructive analysis of test welds will be performed as required to maintain the integrity of the welding program.

D. Coating - All pipe will be cleaned, then coated with coal tar enamel and wrapped with fiberglass and asbestos felt to comply with National Association of Corrosion Engineers TGF-3 specifications for a temperature exposure range of -10^{o} to 160^{o} F. All coating will be applied under

controlled conditions in the yard of a pipeline coating contractor before shipment to the site. The coating will provide excellent protection for the pipe against corrosive or oil-soaked soils as well as withstand mechanical soil stresses. Welded joints will be thoroughly cleaned, primed, coated and wrapped with the same materials used for line coating. Prior to backfilling, all coated pipe will be inspected with an electric holiday detector to determine if coating has been properly applied and all defects, damaged areas and holes will be repaired.

At the White River crossing, the pipe will be coated to the above specifications and will also have a one-inch concrete coating to provide additional durability and to ensure that the pipe has no tendency to float out of its entrenchment.

E. Lowering, Backfill and Cleanup - Pipe will be lowered into the ditch with sufficient sag bends and overbends such that the pipe fits the contour of the bottom of the ditch. In places where rock is encountered, the ditch will be padded with four inches of sand or loose soil before laying the pipe. Once in the ditch, the pipe will be covered with six inches of sand or loose soil before backfilling with any rock-laden soil that might damage the coating. When backfilling is completed and compacted, the ROW will be leveled, restored and seeded with a mixture designated by the proper regulatory agencies. On steep slopes, sandbag retards will be placed in the trench to prevent erosion of the ditch line during heavy rainfall. Also, waterbars, waterbreaks and culverts will be provided, as necessary, to divert runoff and maintain natural drainage.

F. Cleaning and Hydrostatic Testing - After the pipeline is installed in the ditch and backfill completed, a sizing plate and cleaning scrapers will be propelled through the line with compressed air. This procedure will locate any pipeline dents or buckling that must be repaired before operation, and will also clear the line of all soil and other debris; the debris will be caught in a trap at the end of the line. The line

will then be hydrostatically tested to 90% of the specified yield strength of the pipe in accordance with industry standards and Department of Transportation regulations. Hydrostatic test pressure shall be maintained for a minimum of 24 hours. Water used during hydrostatic testing will be disposed of in accordance with any State or Federal permits required.

G. Road and River Crossings - Ditches across small unimproved roads and trails will be cut as part of the normal ditching procedures. Crossing of improved roads will be by boring beneath the traveled surface. If the road is paved, the crossing will be bored and the pipeline will be installed in a 14-inch casing pipe. Where the pipe is cased, vents, insulators, and seals will be used to insulate the carrier pipe from the casing pipe. A minimum of four feet of cover will be provided between the top of the pipe and the bottom of borrow ditches at all road crossings.

At the White River crossing, there will be a minimum of seven feet of cover between the top of the pipe and the river bed. The cover will be gradually increased from the normal three feet beginning 100 feet on either side of the river. Conventional excavating equipment (probably draglines) will be used for digging a trench in the river; the job can probably be accomplished from the river bank, with no need for the equipment to be in the river proper. Meanwhile, the pipeline will be welded into a continuous string on the river bank, where it will also be hydrostatically tested and concrete field joints installed. The entire string will then be pulled into the trench excavated in the river; the actual installation of the line in the trench will be done in a short period of time and backfilling will be completed quickly thereafter. In addition to the pipe coating, the pipeline at the river will also have a one-inch concrete jacket to provide mechanical protection against outside damage and to ensure that the pipe has no tendency to float out of the trench. After installation, the river bank will be rock rip-rapped to prevent erosion.

4.3 SHUTOFF VALVES

Figure 5-4-1 illustrates the entire pipeline system, including the location of the shutoff valves. The shutoff valves installed at both ends of the pipeline will be equipped with motor operators to facilitate remote and quick shut-off in the event of an emergency or accident. Shutoff valves will also be installed at other points along the pipeline in compliance with Department of Transportation regulations, Part 195, and in consideration of:

- Terrain and drainage systems traversed
- Population centers
- Wildlife and fishery habitat
- Public water supplies and significant water bodies
- Hazardous geologic areas
- Scenic values

Based on the above considerations, valves will be located: at the Tract C-a pumping station (this will be an automatic station shutdown valve); at the head of East Spring Creek; on both sides of Douglas Creek; on both sides of the White River; and, at Amoco's Rangely delivery station. At RBOSP request, the Department of Transportation is currently reviewing the guidelines for valve locations to determine if any changes are necessary.

Initially, the pipeline will probably be operated from Tract C-a. Later, the pipeline will be operated remotely, probably from Amoco's remote system operation at Casper, Wyoming.

4.4 CORROSION CONTROL

All external cathodic protection will be provided by groundbed installations using either impressed current or galvanic systems. Impressed current beds will consist of rectifiers, direct burial cable, and graphite

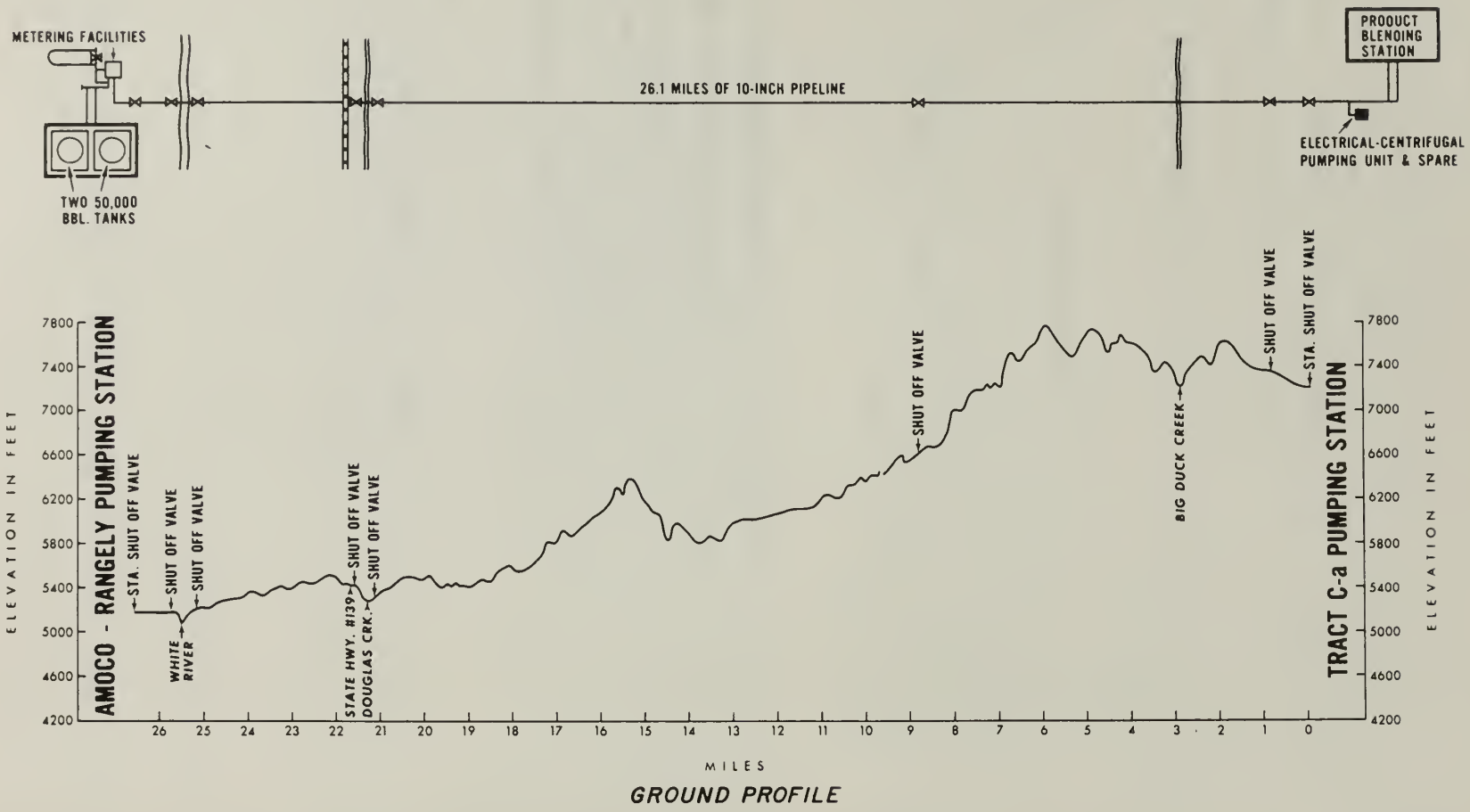


Figure 5-4-1

PLAN AND PROFILE OF RBOSP PIPELINE TO RANGELY

anodes. Deep well impressed current beds will consist of highly durable cable and alloy cast iron anodes. Galvanic anodes will consist of specially prepared materials such as magnesium or zinc. Design Standards for the cathodic protection system will be in accord with NACE RP-01-69.

Corrosion control coupons (small pipe samples) will be placed inside the pipeline at both the Rangely and Tract C-a stations to monitor internal corrosion rates. Coupons will be removed, analyzed, and replaced every six months. Single wire test stations will be installed at various points along the pipeline during construction to provide for the measurement of pipe-to-soil potentials. There will normally be one test station per mile, but additional test stations will be installed where the RBOSP line crosses another pipeline and there is a possibility of corrosion-causing current between the two pipes.

Inspections every two months will be part of the maintenance program for the cathodic protection system. The bi-monthly inspections will include a visual inspection and reading of rectifier voltage and amperage.

Annual inspections will be made of all buried pipeline facilities. This will include measurement of pipeline potentials at the electrical test stations, exposed valves, and at other locations where interference may occur. Periodic aerial inspections will also be made to look for leaks, potential land slides, construction activities by others near the pipeline, and other potential problems.

Whenever previously buried pipe is exposed, an examination will be made of the coating and the pipe. If the coating has deteriorated or if the pipeline is bare, an inspection for corrosion will be made. If corrosion is found, further investigation will be made as to the severity and extent of corrosion, and repairs will be made as necessary. If the pipeline is cut, a similar inspection will be made of signs of internal corrosion and appropriate measures shall be taken, as necessary.

4.5 LEAK DETECTION

The pipeline will be continuously monitored for leaks through pressure and flow instrumentation. A major leak will automatically cause pumping stations to shut down. Periodic aerial inspections will also be made.

CHAPTER 5
WATER MANAGEMENT

Water for the Modified In Situ (MIS) development of Tract C-a will be supplied by a mine dewatering system, wells and mine seepage water, and by MIS retort water. The mine dewatering system will be continually modified with the addition of new wells and abandonment of old ones throughout the operation. Mine dewatering is expected to provide more than enough water for the projected demand.

RBOSP has conducted an active program of securing rights to the ground and surface water supplies needed for Tract C-a development within the prior appropriation doctrine under which Colorado administers the use of its water.

Most of the groundwater in the vicinity of Tract C-a is part of a basin-wide aquifer system wherein the water, in a state of transient storage, moves slowly towards discharge into surface streams in the area. Since most of the groundwater will be reinjected off the tract after removal for underground mining and MIS retorting operation, the overall effect of dewatering on the groundwater aquifers will be minimized.

Storm water control facilities are illustrated on Figure 5-5-1.

Further details on water facilities can be found in Section 6, Chapter 6, Water Quality Control.

5.1 MODULAR DEVELOPMENT PHASE

A. Water Flow - The overall water flow for the Modular Development Phase (MDP) is illustrated on Figure 5-5-2. The major portion of the water from mine dewatering wells and treated mine seepage water will be

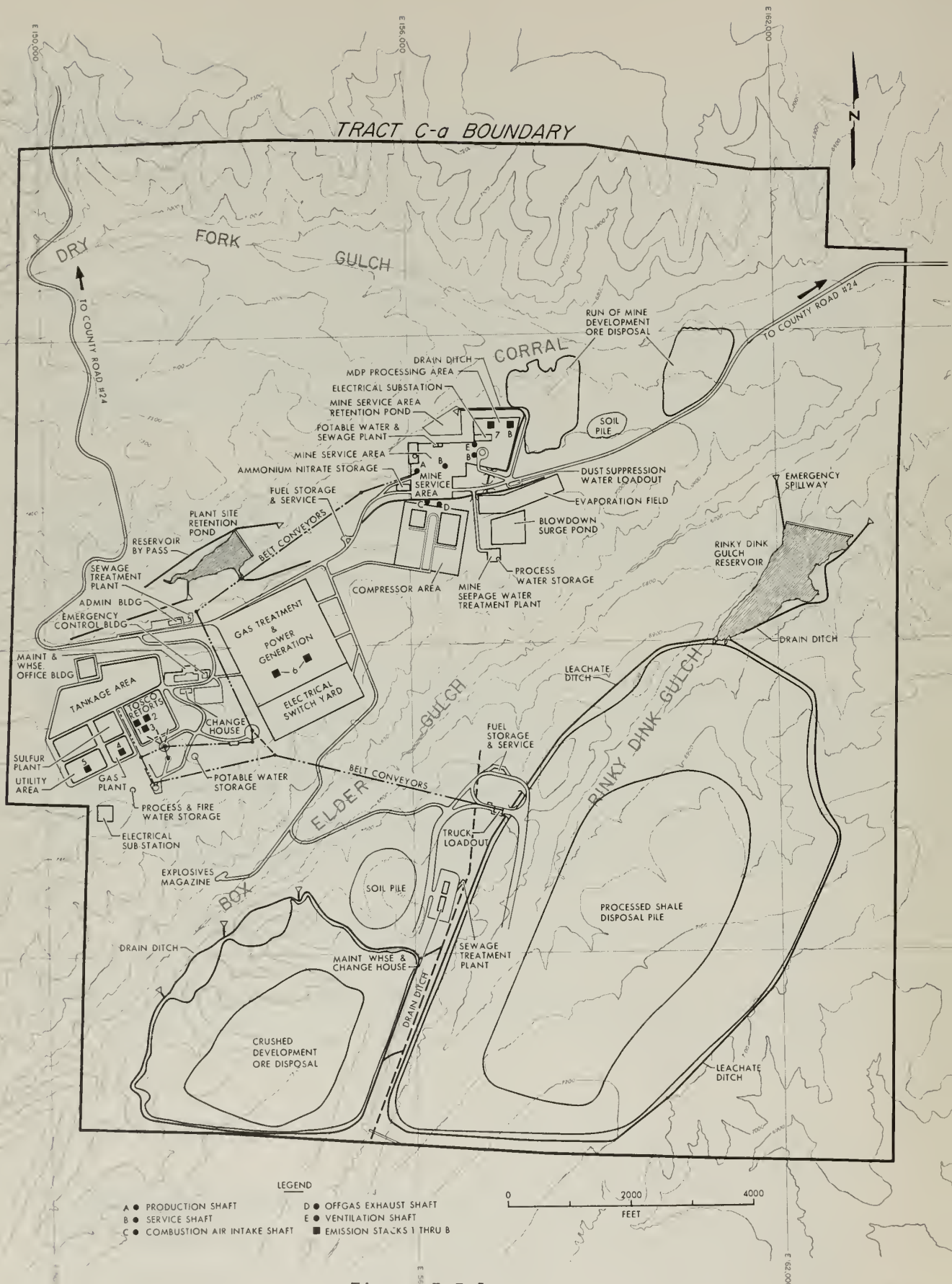


Figure 5-5-1

SITE PLAN

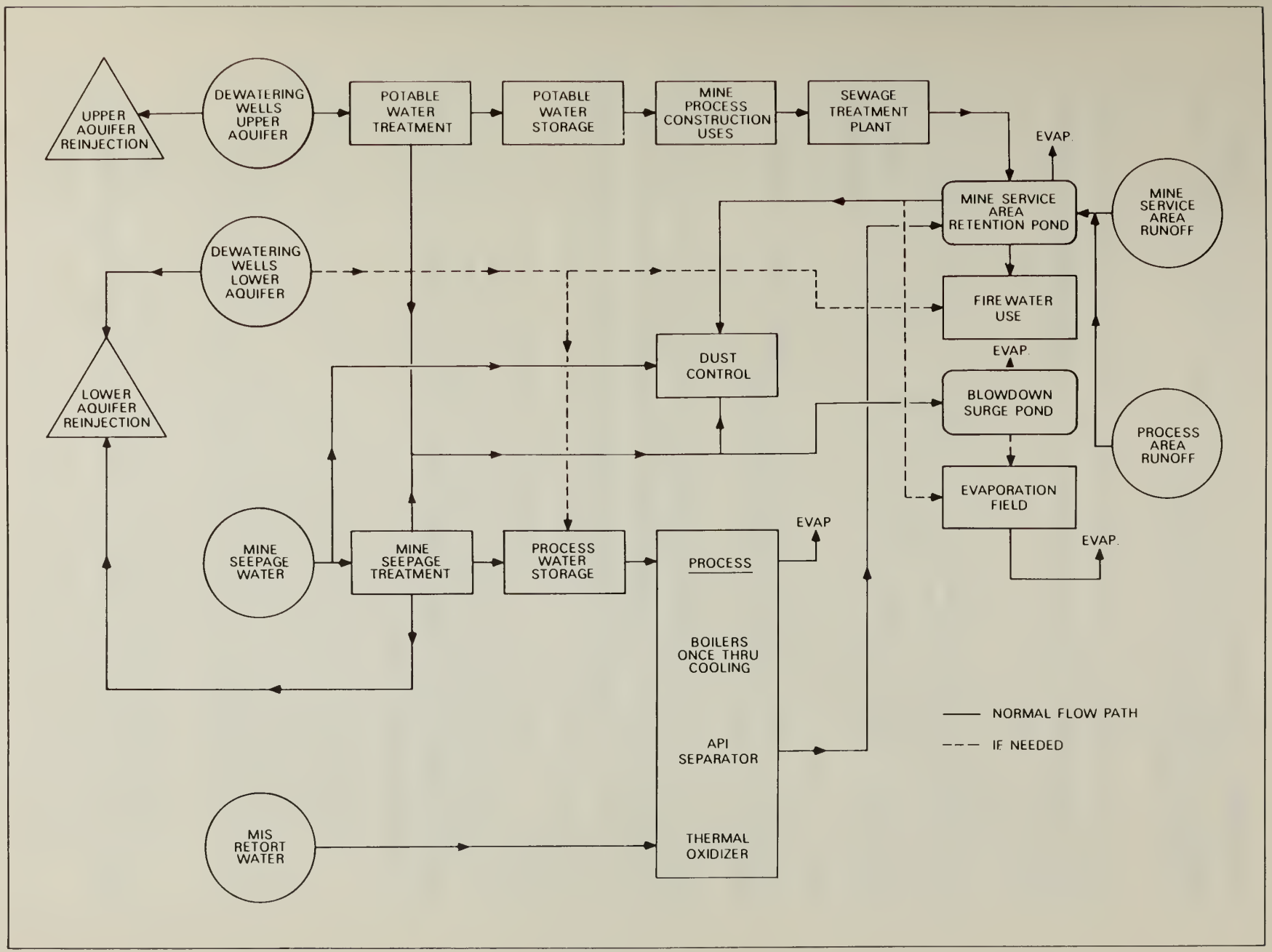


FIGURE 5-5-2

WATER FLOW - MODULAR DEVELOPMENT PHASE

reinjected. The MIS retort water will be evaporated in the thermal oxidizer. Surface runoff and sewage effluent will be recycled for use as process water and for dust control.

The surplus wastewater and blowdown water will be disposed of by means of an evaporation field and sprinkling on the development ore disposal areas.

B. Dewatering and Reinjection - During the MDP, several dewatering sites will be located in the vicinity of the mine shafts and mine service area. Each site will contain two wells: one for the upper aquifer and the other for the lower aquifer. Dewatering wells will be abandoned and added as operations expand into the Commercial Phase. The mine seepage water that is not used consumptively will be treated and reinjected along with the water from the dewatering wells.

Water will be collected from the dewatering wells and distributed to the reinjection wells by a piping system. The reinjection of water will help maintain the natural flow of springs and minimize effects on wells. The reinjection wells will be located to enhance this augmentation effort.

The reinjection technique will allow the project to comply with the zero discharge concept for surface waters and will reduce major disturbance of the groundwater aquifers.

C. Process Water Storage and Distribution - The water required for boiler feed water and thermal oxidizer flue gas cooling will mostly come from the dewatering system (mine seepage water). This process water will be distributed to points of usage from a small storage tank.

D. Potable Water Supply and Distribution - The supply for potable water will be drawn from dewatering wells which tap the upper aquifer.

The potable water system will include a storage tank and a reverse-osmosis water treatment system which will provide water of an acceptable quality. The size of the system is based upon the maximum usage by the people that will be employed on the tract at any one time.

E. Fire Protection Water - Line sizes and storage capacity will comply with the fire codes. A storage capacity of 500,000 gallons will be reserved in the mine service area retention pond. One 750 GPM diesel-driven pump and one 750 GPM electric motor-driven pump will provide fire water flow and pressure. Additional water will be provided by the dewatering system pipeline. See Section 6, Chapter 3, Fire Prevention and Control.

F. Sanitary Sewage Treatment Facilities - A single sewage treatment plant will be constructed in the mine service area to handle the sewage from the mine, the processing units and the construction operation during the MDP. Effluent from the sewage treatment plant will be stored in the mine service area retention pond and used for fire protection, process water and construction and haulroad dust control.

G. Surface Runoff, Diversion and Retention - Two categories of surface runoff must be considered. One is runoff water originating outside the plant facilities and the other is water originating inside the plant facilities and construction sites. Each of these waters will have to be handled separately in order to comply with the zero surface water discharge concept as discussed in Section 6, Chapter 6, Water Quality Control.

Surface runoff originating outside the plant site, mine service facility and disposal areas will be allowed to continue its natural flow into the Corral Gulch and Box Elder Gulch drainage systems.

A retention pond will be constructed to collect the runoff from the mine service area facilities. This pond is located at the low end of the mine service area. The runoff water will be recycled as process and

dust control water. Any excess will be disposed of by evaporation from the retention pond or in an evaporation field located near the mine service area.

Runoff water from the development ore stockpiles (ROM and crushed) will be collected in a series of ditches where sediment will be permitted to settle. The water will normally evaporate in the ditches. In the event of excessive runoff, the settled water will be discharged to natural drainages.

H. MIS Retort Water - The water produced during the Modified In Situ retorting process is called MIS retort water. The handling of this water is discussed in Section 3, Chapter 2.1.D.8, Processing.

5.2 COMMERCIAL PHASE

A. Water Flow - The water flow for the Commercial Phase is shown on Figure 5-5-3. Less water will be reinjected and more will be consumed during the Commercial Phase than in the MDP.

Mine seepage water will be treated and combined with water from the mine dewatering wells for reinjection. The MIS retort water will be steam stripped; part will be distilled for use in the process and the remainder will be used for processed shale moisturizing. Rinky Dink Reservoir will store contaminated runoff and leachate which will be used for dust control at the disposal area. Surface runoff and sewage effluent from the plant and mine service areas will be recycled for use as process water or dust control.

B. Dewatering and Reinjection - As now planned, the MDP dewatering well system will be expanded for the Commercial Phase when the dewatering well system will reach a maximum of 19 dewatering sites. Each site will contain two wells: one for the upper aquifer and one for the lower aquifer. Maximum dewatering with wells during this phase is projected

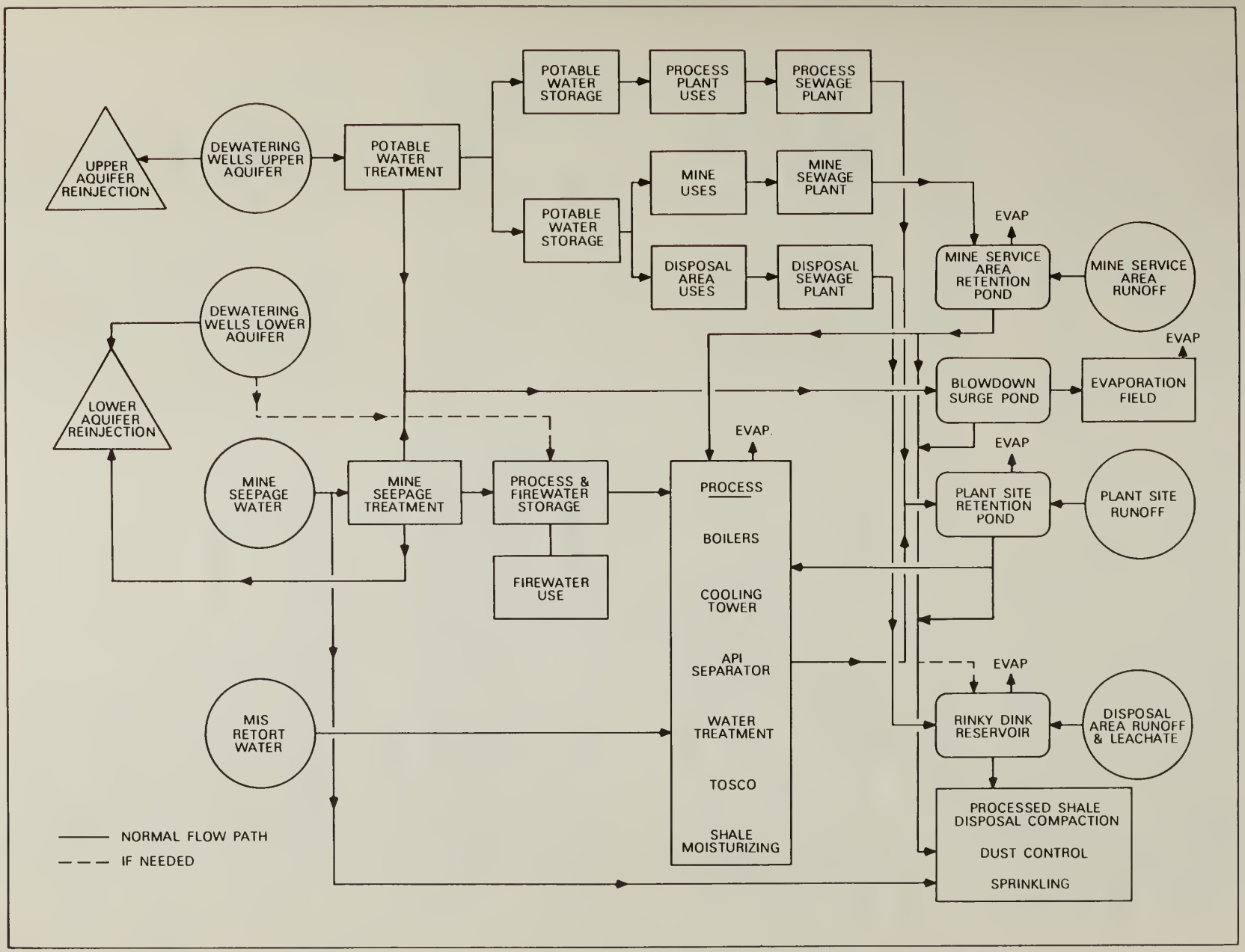


FIGURE 5-5-3

WATER FLOW - COMMERCIAL PHASE

to be about 17 cubic feet per second (cfs). Underground facilities for handling mine seepage water are discussed in Section 2, Chapter 6, Mine Design. It is estimated that up to 8 cfs of mine seepage water will be pumped to the surface during the Commercial Phase of the project. This water will be used for dust control and sprinkling. The excess will be treated for use in the process and for reinjection along with the excess water from the dewatering wells.

C. Process Water Storage and Distribution - The process water distribution system will be expanded for the Commercial Phase. Water from the dewatering system will be conveyed to a storage tank and then pumped throughout the project area to points of use. The process requirements for the Commercial Phase include the TOSCO II retort facility, gas treatment plant, scrubbers, boilers, cooling towers and processed shale moisturizing. The waste water from process facilities will be used for processed shale moisturizing.

One 7.5 million gallon storage tank (with 5.0 million reserved for fire protection) will be located adjacent to the TOSCO II processing plant.

D. Potable Water Supply and Distribution - The reverse-osmosis water treatment system installed in the MDP will also serve for the Commercial Phase. A storage tank and distribution lines will be added to serve the Commercial Phase.

E. Fire Protection Water - Fire protection water will be supplied from the process and fire protection water storage tank. This tank will have 5,000,000 gallons reserved for fire protection purposes and is located at such an elevation that adequate pressure will be available by gravity for all locations except for the very tall TOSCO structures. Two-1000 GPM electric motor-driven booster pumps will be provided in the vicinity of the TOSCO processing area to provide protection for tall structures.

F. Sanitary Sewage Treatment Facilities - The treatment plant installed for the MDP will be adequate to serve the mine service area during the Commercial Phase. Two additional treatment plants will be constructed for the Commercial Phase. One will treat the sewage from the process facility and will be located in the processing plant area. The effluent from this sewage treatment plant will be contained in the plant site retention pond and will be recycled into the process water system. The other sewage treatment plant will be located at the truck shop near the processed shale disposal area. The effluent from this plant will flow to Rinky Dink Reservoir.

G. Surface Runoff, Diversion and Retention - Surface runoff will be controlled throughout the project area. Diversions will be provided around the mine, processing facility, and disposal piles. Surface water originating outside operating areas will be diverted around the facilities and returned to an existing watercourse downstream. Surface runoff originating within the operating areas will be controlled and included in the zero surface water discharge system.

Surface runoff originating off the tract and outside the plant site, mine service facility and disposal areas will be allowed to continue its natural flow into the Corral Gulch and Box Elder Gulch drainage system. A relatively modest diversion system will be required to convey water from Rinky Dink Gulch around the processed shale disposal area and into Box Elder Gulch. A plant site retention pond will be constructed in Corral Gulch to collect the runoff from the plant site. The mine service facility retention pond constructed in the Modular Development Phase will collect the mine service area runoff. The evaporation field will also be used for disposal of excess water. The runoff water will be recycled to the processing facility or used for dust control. Excess water will be pumped to Rinky Dink Reservoir or disposed of by evaporation.

The runoff water from the processed shale disposal area will be caught in lined diversion ditches and run to Rinky Dink Reservoir where it will be retained for use in compaction and dust control requirements on the disposal site.

H. MIS Retort Water - The water produced during the in situ retorting process is called MIS retort water. The handling of the water is described in Section 3, Chapter 3.1.D.2.c, Processing.

CHAPTER 6
COMMUNICATIONS

6.1 TELEPHONE

A. Surface Facilities - Mountain Bell Telephone Company will provide telephone service to Tract C-a from Rangely. Enough circuits will be provided to accommodate intraproject, local and long-distance calls. Switching arrangements will provide interface with permanent underground work areas. Other telephone system services that will be available will include telemetering, telecopying and data transfer.

Temporary radio-telephone facilities will be provided to handle communications during the early phases of construction and at the start of the Modular Development Phase (MDP).

The surface telephone system will be a minimal system during the MDP, but will be expanded to a full-service system for the Commercial Phase.

B. Underground Facilities - The project will provide an underground telephone system for the mine and Modified In Situ retorts and permanent work areas for the MDP and Commercial Phase. This system is described in Section 2.

6.2 RADIO

A. Surface Facilities

1. Modular Development Phase - A temporary radio communications system will be operated by RBOSP. The individual construction and operations contractors will provide and operate their own two-way radio system for on-site communications.

2. Commercial Phase - A two-way FM radio system with base stations, mobile units, handie-talkies and remote desk sets will provide internal project communications where telephone communication is not possible. This system will be used to: direct processed shale and waste rock haul, direct compaction and reclamation operations; dispatch operational and maintenance people; and supervise the overall surface facility operation.

Base stations installed in appropriate locations will provide centralized control for the entire system, as well as coupling for the radio and telephone systems. Selected administrative offices will be equipped with remote desk sets for priority or emergency communication. Individual mobile units will be installed in supervisory and other vehicles, as necessary, to provide operations control. In addition, some supervisory personnel will be provided with handie-talkies to relay process information, equipment malfunctions and other necessary operating information while performing their duties in the process facilities.

B. Underground Facilities - The underground radio communications system for the MDP and Commercial Phase is described in Section 2.

6.3 TELEVISION

The use of television for security purposes or monitoring of operations is not anticipated for the MDP. The requirements for the Commercial Phase have not yet been determined.

CHAPTER 7

STORAGE AND DISTRIBUTION OF FUEL AND OTHER SERVICE PRODUCTS

This chapter describes the plan to supply diesel fuel and other service products required to operate mobile equipment during construction and operation of the project. Also described are the storage, distribution and waste disposal facilities necessary for supplying diesel fuel and service products which include gasoline, lubricating oil, hydraulic fluid and antifreeze. Fuel oil storage requirements for the processing operation is covered in Section 3, Processing.

7.1 SUPPLY, STORAGE AND DISTRIBUTION

The estimated amounts of fuel and other service products needed for the Modular Development Phase (MDP) and Commercial Phase are summarized in Table 5-7-1.

Table 5-7-1

AVERAGE ANNUAL REQUIREMENTS FOR FUEL AND OTHER SERVICE PRODUCTS
(In Gallons)

Products	Modular Development Phase	Commercial Phase
Diesel fuel	1,055,000	5,900,000
Gasoline	46,000	135,000
Motor oil	15,000	45,000
Other lube oils	1,500	5,000
Hydraulic fluid	18,000	52,000
Antifreeze	200	500

Diesel fuel, gasoline, lubricating oil, hydraulic fluid and antifreeze will probably be supplied by one of the parent companies of the Rio Blanco Oil Shale Project. It is expected that these products will be shipped by rail from their respective points of origin to a siding near Rifle and then hauled by truck to Tract C-a.

During the initial construction period, diesel fuel and gasoline will be stored in skid-mounted tanks at the site.

Motor oil and other fluids will be stored in the durable containers in which they are shipped from suppliers. Permanent tanks for diesel fuel and gasoline will be buried and protected to prevent corrosion. Tank storage capacities are shown in Table 5-7-2.

Table 5-7-2

STORAGE CAPACITY
(In Gallons)

Product	Mine Service Area	Processed Shale Disposal Area	Processing Plant Area	Total Capacity
Diesel Fuel	130,000*	40,000	-0-	170,000*
Gasoline	-0-	7,500	7,500	15,000
Motor Oil	1,000	1,000	100	2,100
Other Lube Oils	100	100	50	250
Hydraulic Fluid	1,000	1,000	-0-	2,000
Antifreeze	100	100	50	250

*includes 10,000 gallons at the emergency generator station

Fuel will be transferred to day tanks in the underground mining areas by a transfer pump and buried pipeline routed to a bore hole and thence to the appropriate underground facility. Fuel will be transferred to the emergency generator station by a transfer pump and buried pipeline.

A. Modular Development Phase - Buried diesel fuel and gasoline tanks, delivery facilities and fuel transfer facilities for the emergency generator station will be installed at the mine service area in 1978. The other products will be warehoused in suitable temporary facilities to protect them from the weather and damage.

A service station will be provided at the mine service area in conjunction with the storage tanks and delivery facilities. These facilities will be designed and constructed in accordance with the applicable National Fire Protection Association Standards.

B. Commercial Phase - The tankage and service station installed at the mine service area for the MDP will also be adequate for the Commercial Phase. Buried diesel and gasoline tanks and delivery facilities will be installed at the processed shale disposal equipment shop. A gasoline tank will be installed at the processing area maintenance shop. Service station facilities provided in conjunction with this tankage will comply with the applicable National Fire Protection Association Standards. The Commercial Phase facilities will be in place by 1986. They may be constructed earlier to facilitate operations during the Commercial Phase construction period.

Flammable fluids, other than diesel and gasoline, and service products will be stored in permanent pre-engineered metal buildings designed specifically for storage of these materials. Storage and handling of fuel and other flammable liquids will be in accordance with all applicable regulations including the following:

- Tract C-a Oil Shale Lease.
- Design Standards of the American Petroleum Institute, Division of Refining.
- Fire Protection Handbook, National Fire Protection Association, Thirteenth Edition.
- National Fire Codes, National Fire Protection Association, 1975 Edition.
- Colorado Mining Laws, Bulletin 20, Colorado Bureau of Mines.
- Title 30, Part 57, Health and Safety Standards for Metal and Non-metallic Underground Mines, Bureau of Mines, U.S. Department of the Interior.
- Title 30, Part 56, Health and Safety Standards, Sand, Gravel and Crushed Stone Operations, Bureau of Mines, U.S. Department of the Interior.
- Title 29, Part 1926, Sub-part F. Construction Safety and Health Regulations, Occupational Safety and Health Administration, U.S. Department of Labor.

- Safety and Health Rules and Regulations, Colorado Occupational Safety and Health Administration.
- 43 CFR, Part 23.
- 30 CFR, Part 231.

7.2 DISPOSAL OF WASTES

Waste motor oil will be collected and mixed with diesel fuel.

Used antifreeze will be discharged into the sanitary sewer system and decomposed in the sewage-treatment plant. Sludge accumulating in diesel tanks, waste hydraulic fluid, and other waste oils will be burned in the thermal oxidizer in the processing facility.

Solid waste disposal is described in Section 6, Chapter 9. Sewage disposal is described in Chapter 5, Water Management, of this section and in Section 6, Chapter 6, Water Quality Control.

CHAPTER 8
BUILDINGS

8.1 MODULAR DEVELOPMENT PHASE

The only permanent support building provided during this phase is a metal building, with a concrete floor, that will house the diesel engine driven generators. The generators will also serve as the standby power station for the Commercial Phase.

All other support facilities will be housed in trailers and temporary metal buildings especially designed for quick erection and disassembly. The trailers and temporary buildings will be removed when the permanent Commercial Phase buildings are in use.

Any building housing equipment directly connected with mining and processing is covered in Sections 2 and 3.

8.2 COMMERCIAL PHASE

The support buildings planned for each area of the project are listed below:

A. Mine Service Area

- Change house and mine office
- Mine safety and rescue building
- Maintenance shop and warehouse
- Flammable liquids storage

B. Processing Plant Area

- Administration and laboratory building
- Maintenance shop and warehouse
- Change house and office
- Emergency control center
- Flammable liquids storage

C. Processed Shale Disposal Area

- Maintenance shop, changehouse, and warehouse
- Equipment wash and tire shop
- Flammable liquids storage

D. Miscellaneous Buildings

- Gate guard houses
- Pump enclosures

8.3 MAJOR BUILDINGS DESCRIPTIONS

With the exception of the administration building, the structures will be pre-engineered metal buildings. They will be provided with heat, lighting, communications, potable water and sanitary facilities as appropriate. Although these buildings will play an important part in the project's operation, the exact specifications have not been determined.

A brief description of each of the major buildings is given in the following paragraphs.

A. Mine Service Area

1. Change House and Mine Office - This large two-story structure located aboveground in the Mine Service Area will provide:

- Locker, change, and shower areas.
- Mine engineering offices.
- Mine foreman offices.
- Timekeeping office.
- Crew staging and training areas.
- Sanitary facilities.

2. Mine Safety and Rescue Building - This building will be located as close as practical to the mine service shaft.

Mine safety and rescue equipment and supplies will be stored in this building along with ambulances and fire truck. In addition, space will be provided for mine rescue and safety training and administration and emergency medical facilities.

3. Maintenance Shop and Warehouse - This aboveground facility will contain two heavy equipment repair bays complete with overhead crane and auxilliary equipment. It will support the underground shops where the majority of equipment maintenance will be performed. The warehouse portion will provide a receiving and storage area for materials needed in the underground operation.

4. Flammable Liquids Storage - A small flammable liquids storage building will be provided in close proximity to each of the three maintenance shops.

B. Processing Plant Area

1. Administration and Laboratory - The administration and laboratory building will be a two-level building that will accommodate about 85 administrative and engineering personnel. The principle functions of this building will be to provide office space for the administrators, engineers and office personnel; provide areas for conference rooms; provide storage room for supplies and records; and provide a laboratory.

This building will be located just off the main access road north of the process plant area. The location will provide easy access for both employees and visitors.

2. Maintenance Shop and Warehouse - The maintenance shop and warehouse facility will be located near the process plant area and will serve the process plant, gas treatment, material handling, and compressor areas. The services and functions provided in this facility include:

- Machine shop
- Welding shop
- Sheet metal shop
- Piping shop
- Electrical shop
- Instrument repair shop
- General maintenance shop
- Light vehicles maintenance shop
- Paint shop
- Warehouse
- Shop offices

3. Change House and Office - The change house located near the repair shop and warehouse facility will provide:

- Locker, change and shower areas
- Foreman offices
- Sanitary facilities

4. Emergency Control Center - This building will be provided to house fire trucks, ambulance, rescue and safety equipment and a first-aid room. Because of the fire danger at the process plant and oil tankage area, the emergency control center will be located adjacent to the process plant with easy access to the total project.

C. Processed Shale Disposal Area

1. Maintenance Shop, Change House and Warehouse - This facility, located in the processed shale disposal area, will include a heavy mobile equipment repair shop. Mobile equipment to be repaired in the shop will include 150-ton bottom dump trucks, large dozer graders, scrapers, compactors and loaders. The building will also provide a change house for the workers in this area. The change house will provide:

- Locker, change and shower areas
- Foreman offices
- Sanitary facilities

A small warehousing operation will be included to provide the parts and supplies needed for the disposal operation.

2. Equipment Wash and Tire Shop - This facility will be located adjacent to the equipment shop. It will provide equipment washing facilities, tire changing and repair space and tools, as well as storing the tire supply for the surface operations.

CHAPTER 9

EXPLOSIVES STORAGE AND HANDLING

Explosives and blasting agents, primarily ammonium nitrate and fuel oil (ANFO), will be required during the Modular Development and the Commercial Phases of the project. This chapter defines the types and sizes of storage facilities to be constructed, outlines the minimum distances required between magazines and other facilities, and tabulates the estimated daily explosives usage during the Commercial Phase.

The explosives storage facilities will conform to the requirements of the American Table of Distances, 1971 edition published by Institute of Makers of Explosives, and to applicable State and Federal regulations. The Alcohol, Tobacco and Firearms division of the U.S. Treasury Department has incorporated the American Table of Distances into their regulations. The regulations enforced by the Treasury Department are defined in 26 CFR, Part 181. Refer to Section 6, Chapter 2.5.C, "Explosives", for further discussions on safe handling of explosives.

9.1 MODULAR DEVELOPMENT PHASE

During this phase of development individual temporary storage facilities will be provided for each type of explosive required. It is possible that the site planned for Commercial Phase explosives storage may be used for the temporary or Modular Development Phase storage.

9.2 COMMERCIAL PHASE

The requirements for permanent storage facilities for explosives during the Commercial Phase were determined from the daily amount of explosives used and are summarized in Table 5-9-1. Storage requirements are based on a 10 day supply.

Table 5-9-1

AVERAGE DAILY USAGE OF EXPLOSIVES

Blasting Caps	2,100/day
Primers (1/3 lb High Explosive each)	2,100/day
Prilled Ammonium Nitrate	52 ton/day

The blasting caps will be stored separately from all other explosives. The blasting cap magazine will provide about 70 square feet with a 6-foot stacking height to store 3000 pounds of caps.

Primer storage capacity of about 7,000 lbs. will be provided in a separate magazine with an area of 130 square feet utilizing a 6-foot stacking height.

The two explosive magazines storing a total of 10,000 lbs. will be located in accordance with the following minimum distances.

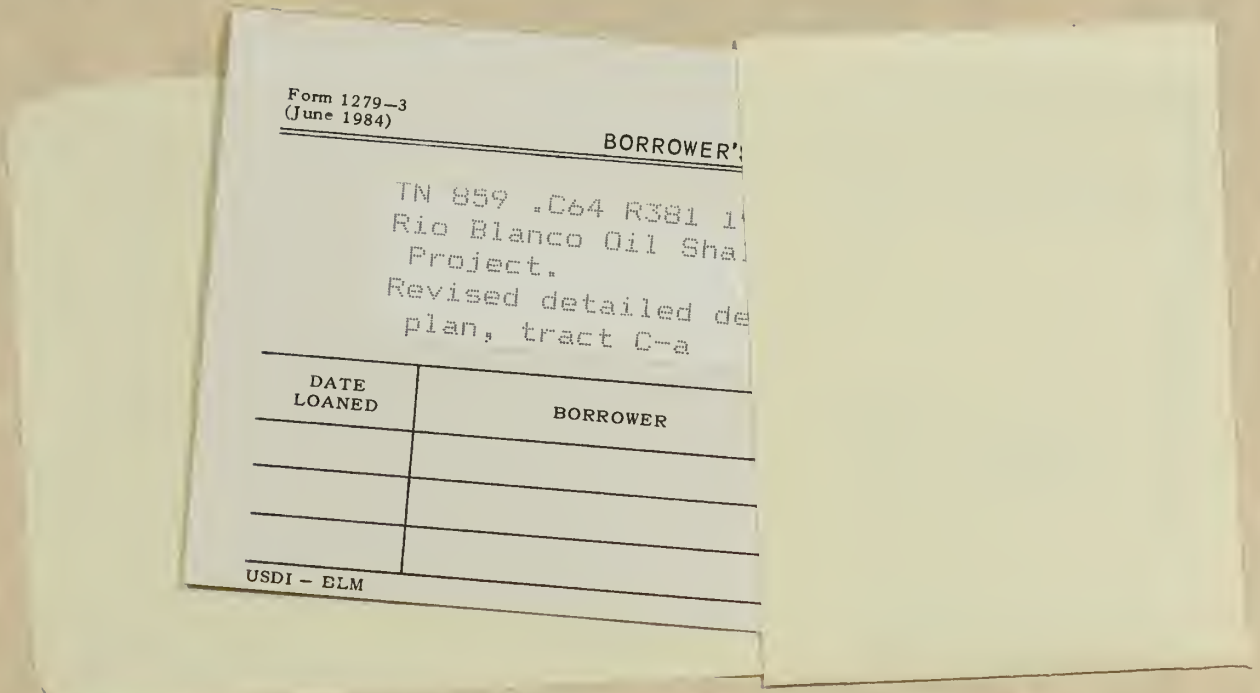
- 1750 ft. from inhabited buildings
- 540 ft. from roads
- 1374 ft. from railroads and highways
- 164 ft. separation of magazines

These distances conform to requirements of the American Table of Distances, CFR 26, Part 181, and are based on unbarricaded storage areas.

The explosive storage facilities are located in Box Elder Gulch and are shown on Figure 5-1-2. They are naturally barricaded by steep canyon walls. All of the distance requirements from the buildings and facilities listed above are exceeded in the proposed magazine locations.

Seven bulk ammonium nitrate storage silos, 75-ton capacity each, will be located adjacent to the main road near the mine production shaft as shown on Figure 5-1-2. Ammonium nitrate is not classified as an explosive and may be located near other facilities. The ammonium nitrate will be

dispensed by gravity into trucks positioned beneath the silos. The ammonium nitrate will be mixed with diesel fuel to form ANFO above ground. The trucks with the ANFO will be taken underground and will deliver the ANFO to the working faces.



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